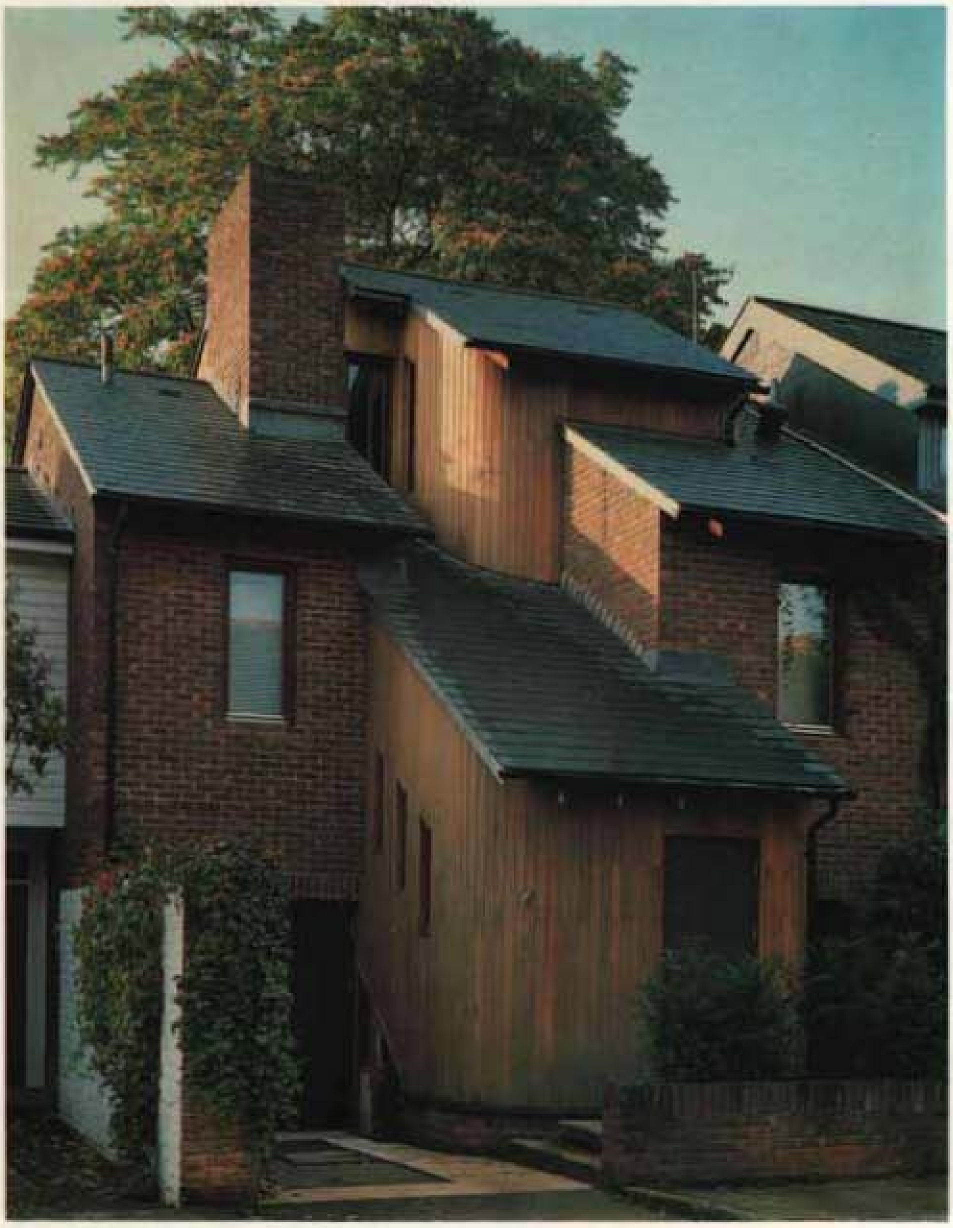
General Information

Report 38

Review of ultra-low-energy homes

A series of UK and overseas profiles



The Reyburn Residence, London

ENERGY EFFICIENCY
DEPARTMENT OF THE ENVIRONMENT, TRANSPORT AND THE REGIONS

BEST PRACTICE PROGRAMME

Foreword

The authors of this report are David Olivier and John Willoughby who were contracted by BRECSU, on behalf of the then Energy Efficiency Office, to investigate and report on ultra-low-energy dwellings in the UK. The purpose of the investigation was to assess how many homes of this type have been constructed and their potential for wider replication. In order to provide a complete picture, relevant details of all homes investigated are included in this report. It should be appreciated that some of the measures do not represent cost-effective options, and their inclusion does not imply recommendation by the DOE. The contributions from Robert Lowe and Derek Taylor, who assisted the authors is gratefully acknowledged.

Additionally, the authors are very grateful to the many designers and owners who gave permission to reproduce copies of their construction drawings, photographs and other copyrighted material in this report.

The authors have made every effort to be accurate in their reporting of the material supplied to them. However, they accept full responsibility for any misinterpretations they may have made.

contents

The Berm House, Caer Llan

Background

In November 1994 BRECSU commissioned a two-phase project to identify and report on 'ultra-low-energy houses' in the UK and elsewhere in Europe. This report is the conclusion of the first phase of this project.

In it a total of 74 UK projects have been identified. One-page Profiles giving details of 40 of these are reported in Section 3 'UK Profiles'. Twenty-eight European schemes have been identified. Profiles on 10 European schemes together with another two Canadian schemes are reported in Section 2 'Overseas Profiles'.

The schemes not reported in the one-page profiles are listed in Section 4 'Additional Projects'.

The schemes were identified either from prior knowledge or through a process of writing to and talking to people known to be active in the field of low-energy design.

The second phase examined ten of the UK schemes in more detail and is the subject of a second report – GIR 39.

Organisation of the report

The overseas profiles are presented in Section 2 before the UK profiles. This allows the UK schemes to be viewed in the context of some of the best schemes from abroad. Each profile is confined to one page. A typical profile consists of a short description of the house(s); details of the floor, walls, roof and glazing; information on air leakage; information on the heating and hot water systems; results of monitoring or measurements of energy consumption where available; and finally a comment on construction costs if known.

The selection of the UK schemes

When searching for UK schemes the following criteria were kept in mind:

- fabric U-values of 0.2 W/m^2K or less
- glazing U-values of 2.0 W/m^2K or less
- a well sealed construction
- total delivered energy less than 100 kWh/m^2yr
- innovative or unusual construction techniques or heating systems and/or
- architectural merit.

Only the very best schemes satisfy all these criteria. Many others fall short in some areas but are included because they are good examples of particular construction techniques or one of the other criteria. The aim was to report on a range of construction types. In addition it was an aim to have schemes from different parts of the UK.

The geographical spread of the schemes is shown on the map below.

Thirty four additional schemes are noted in Section 4 and do not have full profiles. They are in that section for one or more of the following reasons:

- information was received too late for their inclusion in Section 3
- a scheme was known to exist but information could not be obtained
- the scheme was not considered as good as the schemes in Section 3
- the scheme was very similar to a project reported in Section 3.

Map showing distribution of UK schemes

introduction

The selection of overseas schemes

The choice of schemes to review overseas, elsewhere in temperate Europe, or in other similar climates, had to take into account many factors. Among these were the influence of variations in climate, and the degree to which schemes seemed to be genuinely innovative and/or to have actual energy consumption data.

Given the large number of schemes competing for inclusion, the choice was a very difficult one. The selection process led us to feature:

- four schemes from Denmark
- one scheme from the Netherlands
- three schemes from Germany
- two schemes from Switzerland, and
- two schemes from Canada.

The climates of the Netherlands, northern Germany and Denmark are almost equally cloudy, and marginally more 'continental' than sites in the UK on the same latitude. Southern Germany and Switzerland have less wind all year and more insolation, especially in summer. The site in western Canada has the same month-by-month temperatures as south-east England and slightly more summer insolation.

One scheme is included from Ontario, Canada. The significant differences in climate must be borne in mind; this area is 8°C colder than the UK in January, and 6°C hotter in July. However, the design of this house is exceptionally innovative, and far from being a research project, much of its performance was achieved within the financial and other constraints set by speculative housing development. By contrast, most of the projects featured in the UK and elsewhere in Europe are from the self-build, custom-built and social housing sectors.

A note on UK Building Regulations 1995

There are currently three methods of showing Building Regulations compliance for limiting heat loss through the fabric in dwellings:

- an elemental method
- a target U-value method
- an energy rating method.

Detailed information on each of these methods of compliance can be found in Approved Document L of the Building Regulations 'Conservation of fuel and power' 1995 Edition.

The U-value requirements of the elemental method are given in the table below and can be compared with the projects reviewed in this report.

Element	For SAP* ratings of: 60 or less (a)	60 or more (b)
Roofs	0.2	0.25
Exposed walls	0.45	0.45
Exposed floors and ground floors	0.35	0.45
Semi-exposed walls and floors	0.6	0.6
Windows, doors and rooflights	3.0	3.3

* SAP is the Government's Standard Assessment Procedure, see Approved Document L for further details.

Comparison of the U-values in the projects reviewed against those in the table above indicates that many achieve significantly higher standards than those required.

A note on U-values and glazing

In the majority of cases the U-values quoted are those provided by the designers of the project. In several cases it was obvious that the U-values were optimistic; in such cases estimated U-values have been quoted.

Many different window types were found, ranging from two independent single glazed opening lights, through to triple glazing with a fourth outer pane. The convention adopted for describing multiple glazing is to describe the glazing layers from inside to outside. Thus a double glazed sealed unit with a single outer pane is termed 2 + 1 glazing.

The fabric elements are also described from inside to outside.

The schemes and tick ratings

A full list of the schemes is given on the following pages. Every scheme is accompanied by a tick rating on a scale from one to five. Ratings have been given for energy only. Overseas and UK schemes have been judged on the same scale.

Where energy consumption figures are known for the dwelling the tick rating has been awarded on the basis of:

- how much energy the dwelling consumes.

In this case, we arbitrarily assume that proven figures of > 140, 80-140, <80, <30 or <15 kWh/m²yr justify rating a design as ✓, ✓✓, ✓✓✓, ✓✓✓✓ or ✓✓✓✓✓ respectively. This assumes that the scheme is not all-electric and that part of this energy use is fossil fuel for heating and cooking. The energy consumption figures are described as monitored or measured, according to whether there was a full monitoring system in place, or whether the owners simply kept records of their electricity, gas and other fuel bills.

Where energy consumption figures are not known the tick rating takes consideration of how far the design:

- incorporates a balanced combination of measures, to achieve an economic performance from the available technologies, and maximise the annual £ savings per £ spent
- successfully incorporates unusual but thoughtful energy saving details or techniques
- uses innovative techniques, where these seem to offer a better or cheaper approach to energy efficient housing than an adherence to conventional UK practice
- downsizes and simplifies the heating system, as a result of the much lower heat loss of ultra-low-energy dwellings
- addresses energy use by cooking, lighting and electrical equipment, as well as energy use for thermal purposes
- the degree to which the designers appreciated the results of recent research, principally 2-D and 3-D heat flows.

Providing energy ratings for each of the schemes reviewed is difficult because very few have more energy performance data than just gas and electricity bills. To make matters worse, even measured energy performance data from a single house is subject to reservations, because different occupants can have a radical influence on its energy consumption. Ratings awarded on this basis can therefore be approximate only.

Profile	Status	Energy
Overseas Profiles		
Externally insulated masonry		
1 Zero-Energy Houses, Wadenswil, Switzerland (1989-93).	Built (M)	✓✓✓✓✓
2 The Passive Houses, Kranichstein, Darmstadt, Germany (1990-95).	Built (M)	✓✓✓✓
3 The Self-Sufficient Solar House, Freiburg, Germany (1988-95, Built 1991-92).	Built (M)	✓✓✓✓✓
4 Low-Energy Urban Housing, Amsterdam, Netherlands (1993-95).	Design	✓✓✓✓
Precast calcium silicate elements		
5 Werner Residence, Rollengasse, Entringen, Germany (1989).	Built (M)	✓✓✓
Precast concrete		
6 Low-Energy House F, Hjortekaer, Denmark (1978).	Built (M)	✓✓✓
7 Low-Energy House G, Hjortekaer, Denmark (1985).	Built (M)	✓✓✓
8 Denmark IEA Task 13, Copenhagen, Denmark (1992-95).	Design	✓✓✓
Timber frame		
9 Low-Energy House B, Hjortekaer, Denmark (1978).	Built (M)	✓✓✓
10 Waterloo Region Green Home, Ontario, Canada (1992-95).	Built	✓✓✓
11 Zero-Energy Timber frame House, Brunnadern, St Gallen, Switzerland (1991).	Built (m)	✓✓✓✓✓
12 The Duncan House, Victoria, British Columbia, Canada (1983).	Built (m)	✓✓✓✓
UK Profiles		
Masonry with cavity insulation		
1 Wates House, Centre for Alternative Technology, Machynlleth (1976).	Built	✓✓✓
2 Strawberry Hill Low-Energy Houses, Salford, Lancashire (1978-82).	Built (M)	✓
3 *Ryburn Residence, Glentham Road, London SW13 (1984-92).*	*Built (m)*	✓✓
4 Solar Courtyard Houses, Energy Park, Milton Keynes (1986).	Built (M)	✓
5 The Longwood House, Huddersfield, West Yorkshire (1991-92).	Built (m)	✓✓
6 *Lower Watts House, Charlbury, Oxfordshire (1992).*	*Built (m)*	✓✓✓
7 *Cresswell Road Houses, Darnall, Sheffield (1992-93).*	*Built (M)*	✓✓
8 Ash Tree Cottage, Westbury, Buckinghamshire (1993-94).	Built	✓✓
9 Family Housing Association, Brixton, London (1993).	Built (M)	✓✓
10 *The Autonomous Urban House, Southwell, Nottinghamshire (1993).*	*Built (m)*	✓✓✓✓
11 Roaf Residence, Blandford Avenue, North Oxford (1994).	Built	✓✓

Profile	Status	Energy
12 Mill Orchard, Paunton, Bishops Frome, Herefordshire (1992-94).	Built	✓✓
13 *Oasis Of Peace, Porthmadog, Gwynedd, Wales (1994-95).*	*On site*	✓✓
14 The Cowe House, Old Leake Commonside, Boston, Lincolnshire (1992-94).	On site	✓✓
15 Anton Croft, Saffron Walden (1994-95).	On site	✓✓
16 Rockingham House Redevelopment, Bristol (1995/6).	Design	✓
Externally insulated masonry		
17 Midsummer Cottages, Futureworld, Milton Keynes (1993-94).	Built	✓✓
18 Kendal, Cumbria (1993-95).	Design	✓✓
Externally insulated rammed earth		
19 Elmsett Ecological House, East Suffolk (1993-95).	Design	✓✓✓✓
Internally insulated masonry		
20 Low-Energy House, Kirkhill, Inverness, Scotland (1990).	Built	✓
In-situ concrete		
21 Warmhome 200, Glengormley, Newtownabbey, Northern Ireland (1988).	Built (M)	✓✓
22 Embleton Residence, Twyford, Berkshire (1994-95).	On site	✓✓✓
23 The Energy Showcase, Lyonshall, Herefordshire (1990-95).	Design	✓✓✓✓✓
Timber frame factory-assembled		
24 L E C S Housing, Saxmundham, East Suffolk (1983).	Built	✓✓
25 Two Mile Ash, Milton Keynes (1985).	Built (M)	✓
Timber frame site-built		
26 Lifestyle 2000, Energy Park, Milton Keynes (1986).	Built (M)	✓✓
27 *TTL Concept House, Futureworld, Milton Keynes (1994).*	*Built*	✓✓
28 *Self-Build House, St Harmon, Radnorshire, Wales (1994).*	*Built*	✓✓
29 Self-Build Houses at Walter Street, Bristol (1995).	On site	✓✓
30 Low-Energy House, Great Oxendon, Market Harborough, Leicestershire (1984).	Built	✓✓
31 Potters Bar Eco-House (1995).	Design	✓✓✓
32 *Birchdene Drive Self-Build (1995).*	*On site*	✓✓
33 Crickhowell Tele-Village, Powys, Wales (1994-95).	Design	✓✓
34 Four-Bed Detached House, Futureworld, Milton Keynes (1994).	Built	✓✓
35 *'Window' Two-Bed Detached House, Futureworld, Milton Keynes (1994).*	*Built*	✓✓

Profile	Status	Energy
Steel-frame		
36 Four 1/2-Bed Apartments, Futureworld, Milton Keynes (1994).	Built	✓✓
37 Green Street, Festival Park, Victoria Heights, Ebbw Vale, Wales (1991).	Built	✓
Earth-sheltered		
38 *The Berm House, Caer Llan Field Studies and Conference Centre, Lydart, Monmouth, Gwent, Wales (1986-87).*	*Built (m)*	✓✓✓✓
39 Hockerton Houses, Southwell, Nottinghamshire (1995).	Design	✓✓✓
40 Kings Cross Eco-House, London (1994-95).	Design	✓✓✓

ABBREVIATIONS

(M) = Monitored in detail usually with external funding

(m) = Measured energy consumption (based solely on fuel bill data)

NOTE: Profiles shown in italics are featured in more detail in General Information Report 39.

EXTERNALLY INSULATED MASONRY

Zero-Energy Houses, Wadenswil, Switzerland (1989-93)

Ten 3.5-storey 240 m² semi-detached houses, including the cellar. Four, type A, are 'zero-energy'; six, type B, are 'ultra-low-energy'.

Architect: Ruedi Fraefel, Gruningen.

Engineer/Project Manager: Dr Ruedi Kriesi, 8820 Wadenswil.

Wadenswil town council provided the land at less than market value, and required the purchasers of all plots to erect 'ultra-low-energy' houses. The project aimed to show that 'zero-energy' houses could be built at acceptable costs.

Basement floor: Concrete raft upon 120 mm extruded polystyrene, weak concrete blinding, gravel (U-value = 0.19 W/m²K).

Basement walls: 200 mm in-situ concrete, 150 mm extruded polystyrene, drainage material (U-value = 0.16 W/m²K).

Above-ground walls: Plaster, 150 mm dense concrete block, externally insulated with 180 mm extruded polystyrene, rainscreen cladding (U-value = 0.15 W/m²K).

Roof: 100 mm mineral fibre, 50 mm extruded polystyrene and 180 mm mineral fibre (U-value = 0.13 W/m²K).

Intermediate floors: 350 mm in-situ concrete.

Windows: (1) S/E/W - 3-glazed with argon and two sputtered low-emissivity coatings, in wood frames (U-value = 1.2 W/m²K); (2) North - 4-glazed, three 25 mm air gaps, two low-emissivity films, in wood frames (U-value = 0.85 W/m²K).

Air leakage: Measured 0.3-0.4 air changes per hour (ac/h) at 50 Pa. Roof has extremely heavy-duty vapour barrier.

Ventilation: Ground-coupled mechanical ventilation and heat recovery.

Water heating: Type A houses - 33 m² solar collectors and a small seasonal heat store. Type B houses - 9 m² collectors provide solar-heated water for about eight months of the year. Heat recovery from waste water in house 1.

Space heating: ultra-low-temp. underfloor space heating system. The necessary floor temp. is only 26°C at an external temperature of -10°C. The low temperatures, and the floor thermal capacity, make the system largely self-balancing and help to stabilise internal temperatures.

The solar collectors are glazed with a polycarbonate honeycomb material and can produce 25°C water on most cloudy winter days.

Type A - supplied mainly from solar heat piped directly into the concrete floors, and partly from stored solar heat in periods of freezing fog.

Type B houses - gas-fired cogeneration unit chosen so as not to impose peaks on the national electricity grid.

One type A house has a woodstove, with elaborate precautions to avoid heat loss by conduction and convection.

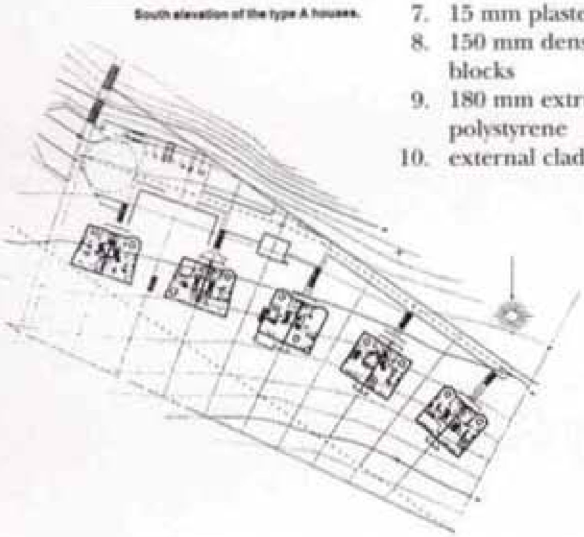
Lighting and appliances: Mostly energy efficient, chosen from products already on the Swiss market.

Cooking: Electric induction cookers.

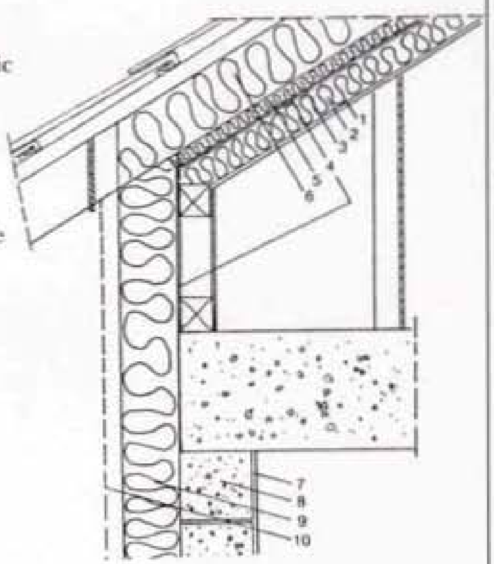
Energy use: House type A – 14 kWh/m²yr excluding the contribution from solar heat but including household electricity.

Costs: Type A 15% overcost compared to the minimum in the Zurich building code, type B 10%.

South elevation of the type A houses.



1. plasterboard
2. 100 mm mineral fibre
3. 12 mm hardboard
4. 3 mm bituminous plastic vapour barrier
5. 50 mm extruded polystyrene
6. 180 mm mineral fibre
7. 15 mm plaster
8. 150 mm dense concrete blocks
9. 180 mm extruded polystyrene
10. external cladding



overseas profile 2

EXTERNALLY INSULATED MASONRY

The Passive Houses, Kranichstein, Darmstadt, Germany (1990-95)

Four 2.5-storey 156 m² terraced houses, plus unheated cellars.

Several years of background research preceded the construction of the project. In this phase, the researchers calculated in detail the influence of the various heat loss mechanisms, the influence of solar gains, etc. Detailed monitoring is underway, with no less than 180 sensors in one terrace of four houses.

Designer Institut Wohnen und Umwelt. A dynamic thermal model was used which separated the radiative and convective heat fluxes within the houses and to and from the thermal mass. Funded by Darmstadt City Council and the Government of Hessen.

Rather like Wadenswil (overseas profile 1), aimed to demonstrate techniques which are commercially available now and could be successfully applied today, as an integrated combination, in ultra-low-energy houses. Technologies which could increase the risk of failure were omitted.

Floor: Suspended in-situ concrete, insulated underneath with 200 mm expanded polystyrene, above an unheated cellar (U-value = 0.16 W/m²K).

Walls: 175 mm calcium silicate blocks, 275 mm expanded polystyrene, adhesive-bonded, cement-sand-lime render on mesh (U-value = 0.14 W/m²K).

Roof: Timber, with 400 mm mineral fibre between Swedish masonite I-beams, and turf-covered (U-value = 0.09 W/m²K). Green roofs are now common in Germany for ecological housing.

First/Second floors and stairs: In-situ concrete.

Windows: 3-glazed with krypton and two sputtered low-emissivity coatings, with 8 mm spaces, in wood frames (U-value = 0.7 W/m²K). A special moulding was made from polyurethane foam insulation, in order to cover the edge and reduce the thermal bridging caused by the frame and metal spacer bars.

Air leakage: Tight polyethylene vapour barrier throughout roof. First house 0.4 ac/h at 50 Pa, falling with experience to 0.2 ac/h at 50 Pa by the third and fourth house.

Ventilation: Mechanical ventilation and heat recovery with CO_2 sensors, using a Danish system. Different motors/fans were used, reducing the system's electricity consumption to 40 W per house. The air flow is predominantly to the living rooms by day and the sleeping rooms at night.

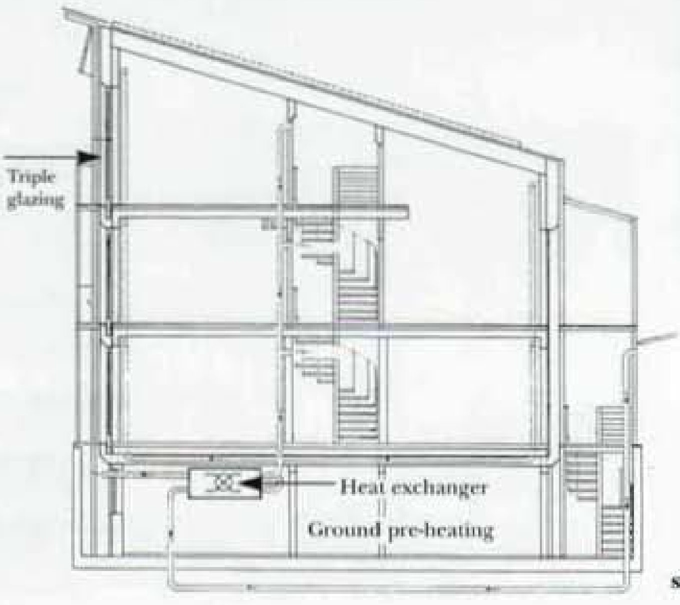
Space and water heating: A central gas-fired condensing boiler, with heat mains to all houses. Solar water heating from wall-mounted collectors spring to autumn. Solar fraction = 66%.

Lighting and electrical equipment: Energy efficient, chosen from the best products on the German market.

Cooking: Gas, which is unusual in Germany, not electricity, to reduce CO_2 production further.

Energy use: Calculated 31 kWh/m²yr, excluding the solar contribution. Measured energy use in 1992-93 was 32 kWh/m²/yr, of which space heating was 10 kWh/m²yr.

Costs: Not known.



south – north cross-section

overseas profile 3

EXTERNALLY INSULATED MASONRY

The Self-Sufficient Solar House, Freiburg, Germany (Project Duration 1988-95, Built 1991-92)

Two-storey 145 m² detached house, with unheated basement containing monitoring equipment. Autonomous for its energy needs.

Design, research and monitoring by Fraunhofer Institute for Solar Energy Systems, Freiburg. Financial assistance from Federal Ministry for Research and Technology, Government of Baden-Wuertenburg and Freiburg City Council.

The house's shape is greatly influenced by the underlying technology. It has a conventional opaque north wall plus a semi-circular, 100% glazed 'solar' wall which extends around from west to east and gives the house a 'modern' architectural appearance. In an average year, the solar wall produces a heat surplus on all but 15 days.

Ground floor: Suspended concrete above basement, 230 mm cellular glass.

Basement walls: 300 mm concrete block, 230 mm cellular glass (U-value = 0.16 W/m²K).

Walls: (1) North - 300 mm calcium silicate block, externally insulated with 240 mm cellulose fibre (U-value = 0.16 W/m²K). (2) Opaque portion of south, east and west - 300 mm calcium silicate block, externally glazed with polycarbonate honeycomb and moveable blinds (U-value = 0.51/0.40 W/m²K with blinds open/closed).

Roof: Flat concrete slab with 230 mm cellular glass (U-value = 0.18 W/m²K). The solar systems are located here.

First floor: 300 mm in-situ concrete.

Windows: 2+2-glazed, with krypton and two sputtered low-emissivity coatings, in wood frames (U-value = 0.6 W/m²K).

Air leakage: 0.3 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery with earth-buried tubes, using 16 W.

Space and water heating: Backup space heat from catalytic hydrogen (H_2)combustion; heat is distributed adequately by the forced ventilation system.

14 m² of novel collectors plus a 1 m³ water store provide an 86% solar fraction for hot water, and are backed-up by stored H_2.

Space cooling: No active system. With the blinds closed, comfort is as good as in traditional high thermal capacity buildings.

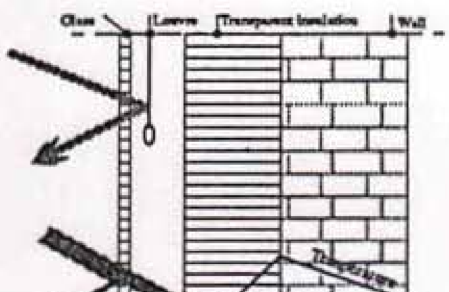
Lighting and electrical equipment: Energy efficient; items already on the German market.

Electricity supply: Roof-mounted PV system. After battery charging, the cells' surplus output is converted by electrolysis into H_2, a storable fuel. A fuel cell converts this to electricity as required.

Energy use: Design fossil fuel use zero. In 1994, the total electricity consumption was 800 kWh. The total heat demand met by stored H_2, ie over and above the contribution made by the solar thermal systems, was 76 kWh.

Costs: Being a research project, not all measures are intended for immediate application. The solar energy systems, the thermal store, the ventilation system and all the 'passive' systems have worked well. The battery and fuel cell gave problems, but these are now resolved.

Mass Storage System



overseas profile 4

EXTERNALLY INSULATED MASONRY

Low-Energy Urban Housing, Amsterdam, Netherlands (1993-95)

Sixteen 100 m² flats, representing the Netherlands contribution to IEA Task 13. Part of a larger inner-city development. Striking architectural form.

Funded by NOVEM, the Netherlands Agency for Energy and the Environment. Architects Atelier Z, Rotterdam. Services engineering by the Department of Mechanical Engineering, Delft University of Technology. Thermal design of building envelope and co-ordination by Damen Consultants, Arnhem.

Floor: Concrete suspended ground floor with 200 mm expanded polystyrene, on pile foundations (U-value = 0.15 W/m²K).

Walls: 200 mm dense concrete block with 200 mm polystyrene foam (U-value = 0.17 W/m²K). South and north facade: wood frame construction with 200 mm mineral wool.

Roof: 250 mm polystyrene foam (U-value = 0.15 W/m²K).

Upper floors: 200 mm concrete.

Stairs: Concrete.

Windows: 3-glazed with krypton and two sputtered low-emissivity coatings (U-value = 0.7 W/m²K).

Air leakage: Designed to be < 30 p/s at 10 Pa.

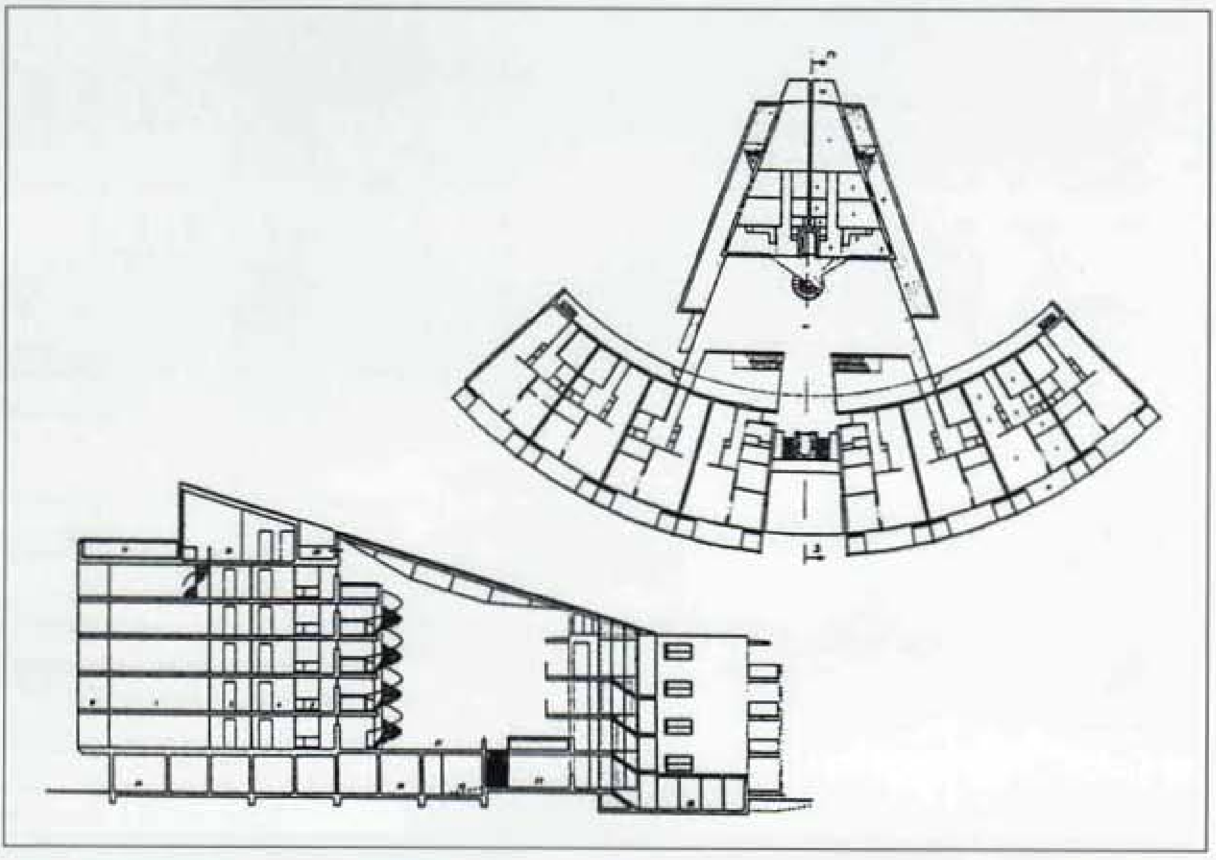
Ventilation: Mechanical ventilation and heat recovery.

Heating: Space heating by condensing gas-fired boiler linked to convectors. Solar collectors for domestic hot water. Backup water heating from the boiler.

Lighting and electrical equipment: Hot-fill washing machines to reduce electricity demand further.

Energy use: Predicted for space heating, about 10 kWh/m²yr. Helped by compact building shape.

Costs: Not published. Project aim goes beyond immediate cost-effectiveness.



PRECAST CALCIUM SILICATE ELEMENTS

Werner Residence, Rollengasse, Entringen, Germany (1989)

Semi-detached 2.5-storey 280 m² house, built on small infill site in village centre. Privately funded. Designed to be both low-cost and low-energy. Gable end faces south.

Client and designer Johannes Werner, EBOK Consultants Tubingen. Monitoring by owner and by Institut Wohnen und Umwelt, Darmstadt.

Floor: Concrete slab-on-ground, 75 mm extruded polystyrene (U-value = 0.24 W/m²K). No cellar.

Walls: (1) 175 mm calcium silicate elements with thin mortar joints, 180 mm expanded polystyrene, external render (U-value = 0.20 W/m²K); (2) small areas with less insulation (U-value = 0.26/0.32 W/m²K).

Roof: 300 mm mineral fibre in sloping portion, 250 mm mineral fibre in cheeks of dormers (U-value = 0.15 W/m²K).

First floor: 300 mm in-situ concrete.

Windows: Double glazed with argon and one sputtered very low-emissivity coating, in wood frames (U-value = 2.1 W/m²K).

Air leakage: Top half, which is let as a separate flat and has three dormers, which are hard to seal, 0.7 ac/h at 50 Pa. Lower half, below the concrete floor, is plastered masonry and has no timber elements, and is thought to be tighter, but is not yet tested.

Ventilation: Exhaust-only from 'wet' rooms, with Swedish air inlets in all other rooms and no heat recovery. Separate systems for the ground and first floors. Initially, the electricity consumption of the ground floor system was 20 W for an airflow of 120 m³/hr. It fell to 9 W after a more efficient motor was retrofitted in 1994.

Space and water heating: Oil-fired high efficiency boiler and tall, single column radiators. Peak heat load 33 W/m² at 22°C inside, -16°C outside. Water heating via a mains-pressure storage tank.

Energy use: Useful space heating energy predicted to be 63 kWh/m²yr; measured 64 kWh/m²yr. Electricity use 8 kWh/m²yr. Low electricity use is particularly notable.

Costs: Small, compared to building code. Total budget was DM 1960 (£800) per m², which is about normal for Germany. Careful design helped to achieve this. The use of large calcium silicate elements, numbered in the factory and lifted into place by crane, reduced costs compared to the normal German wall of hand-laid clay blocks. At the time, the exhaust-only ventilation system was much cheaper than a balanced supply-and-extract system.

PRECAST CONCRETE

Low-Energy House F, Hjortekaer, Denmark (1978)

Two-storey, 126 m², with a heated basement. One in a development of six detached houses. The researchers' aim was to go as far as possible with the techniques of the time, in a large range of construction systems and architectural styles, to reduce energy demand for heating. Cost-effectiveness was not the only aim, or even a primary aim.

Energy design expertise by the Thermal Insulation Laboratory, Technical University of Denmark, Lyngby. Architectural design came from six different practices, collaborating with local building firms, who specialised in different construction techniques.

Basement floor: Concrete slab of 120 mm, resting on 200 mm high-density mineral fibre.

Basement walls: Precast concrete sandwich elements, insulated with 175 mm high-density mineral fibre (U-value = 0.21 W/m²K).

Above-ground walls: Similar to basement walls, but with 200 mm mineral fibre (U-value = 0.19 W/m²K).

Roof: Flat, precast 200 mm concrete slab with 300 mm rigid mineral fibre, followed by waterproofing and 100 mm concrete (U-value = 0.13 W/m²K).

First floor: 200 mm precast prestressed hollow-core concrete slab.

Stairs: Concrete.

Windows: 3-glazed in PVC frames plus external insulating shutters (U-value = 2.4/0.43 W/m²K when open/closed). House was designed for maximum passive solar gains, with about 70% of the glass facing south.

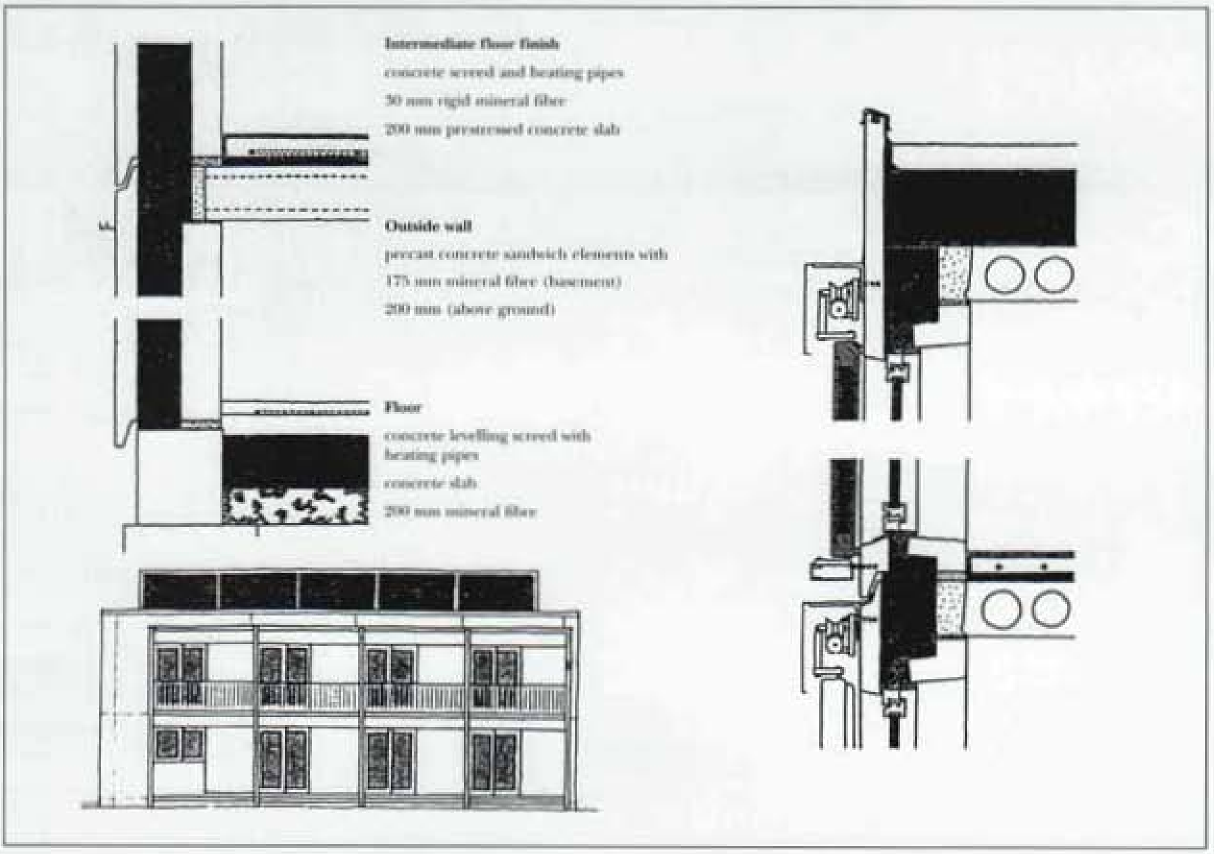
Air leakage: 0.07 ac/h in tracer gas tests and 0.7 ac/h at 50 Pa in a blower door test. Measured in 1982, these figures suggested that the house had become 10-20% leakier than when it was new.

Ventilation: Mechanical ventilation and heat recovery.

Space and water heating: Active solar, with backup from a gas-fired boiler. Underfloor heating to all floors.

Energy use: The requirement was that total energy use for space and water heating, plus ventilation, should not exceed 42 kWh/m²yr for each house. This figure was based on a total target energy consumption of approximately 5000 kWh per year. The measured heat loss was 104 or 144 W/K with shutters closed or open respectively.

Costs: Not known.



EXTERNALLY INSULATED LIGHTWEIGHT CONCRETE

Low-Energy House G, Hjortekaer, Denmark (1985)

Detached 120 m^2 1-storey house.

Energy design by Thermal Insulation Laboratory, Technical University of Denmark, Lyngby.

The most successful features of the 1978 Hjortekaer project were integrated into a single house design. The objective was to use proven technology to save maximum energy, at minimum cost.

Floor: Concrete slab above 200 mm expanded polystyrene.

Walls: 150 mm lightweight concrete elements, of one storey height, 200 mm mineral fibre, 100 mm mineral fibre within timber studs hung from the rafters. Clad with external rendering below ground and with a mixture of timber boarding and sheets of fibre cement above ground (U-value = 0.13 W/m^2K).

Roof: 400 mm mineral fibre between masonite I-beams (U-value = 0.09 W/m^2K).

Windows: Either 2-glazed with external insulating shutters, or 3-glazed without shutters, all in wood frames (U-value = 2.8 or 2.0 W/m^2K when open and 0.5 W/m^2K when closed).

Air leakage: 0.6 ac/h at 50 Pa. Cold weather tracer gas tests indicated 0.03 ac/h, despite the house being site-built. The tight polyethylene vapour barrier in the roof, the plastered walls and the careful sealing of the walls to the ground floor slab contributed to this good result.

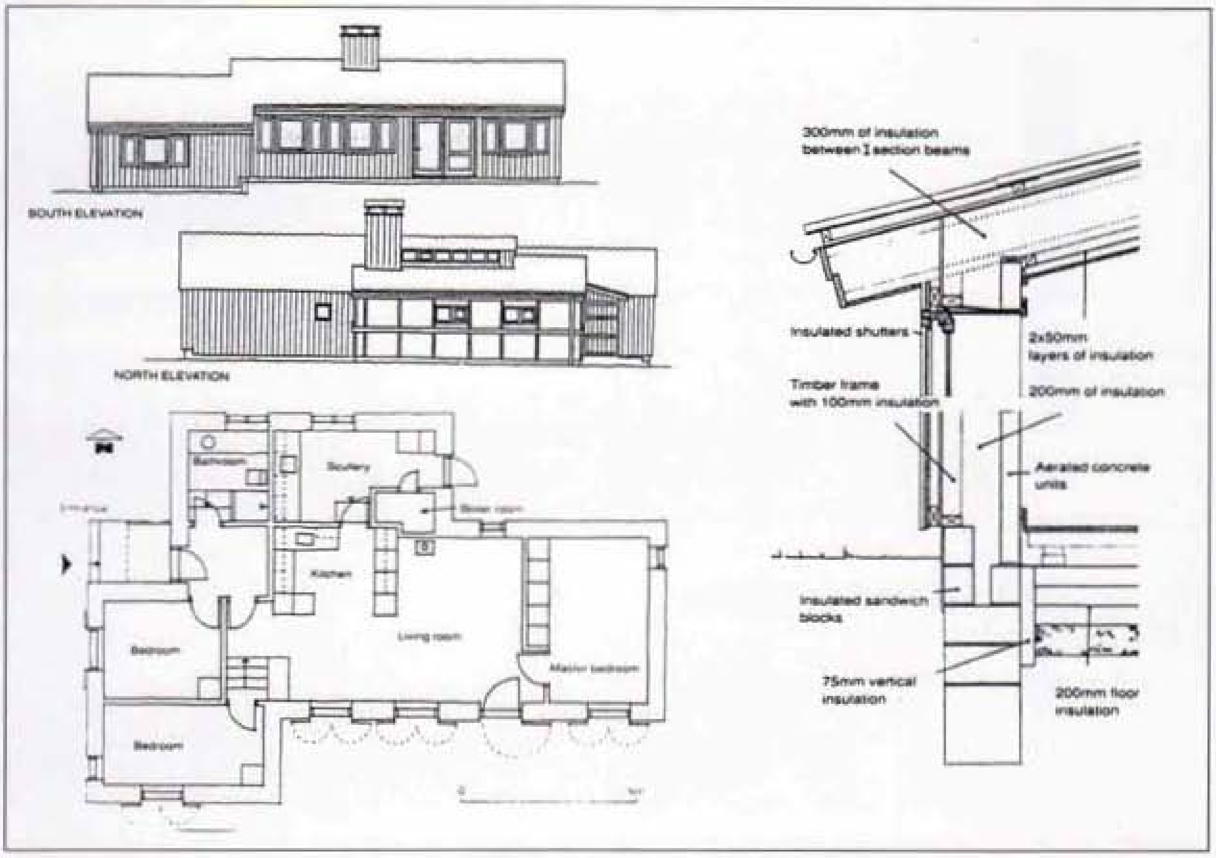
Ventilation: Mechanical ventilation and heat recovery.

Heating system: Fan convector space heating, plus small areas of floor heating in hall and bathroom. Each fan used only 4 W. System designed to be simple and with a quick response. The initial heat source was a low water content 5 kW LPG-fired boiler, but the system could readily utilise district heating in future.

To reduce capital cost, the heating circuit was taken from the hot water storage tank. A woodstove and chimney were installed at the purchaser's insistence, requiring a chimney damper and rather elaborate measures to ensure a safe combustion air supply.

Energy use: Overall 70 $kWh/m^2/yr$. Space heating 20 $kWh/m^2/yr$, which was 23% of the normal figure for new Danish houses in 1985.

Costs: 10% overcost relative to measures required by the 1985 Danish building code. The marginal return on the measures, eg the extra 150 mm of wall insulation on top of the normal 150 mm, was about 3%/year. However, studies suggested that if the relevant products and components were mass-produced, the extra cost would be halved.



EXTERNALLY INSULATED PRECAST CONCRETE

Denmark IEA Task 13, Copenhagen, Denmark (1992-95)

Twelve 2-storey 105 m^2 terraced houses. Currently seeking a host housing association.

Thermal design and window development by the Thermal Insulation Laboratory, Technical University of Denmark.

Floor: Concrete slab-on-ground above 200 mm rigid mineral fibre (U-value = 0.15 W/m^2K).

Walls: Precast storey-height dense concrete elements, externally insulated with 300 mm mineral fibre (U-value = 0.11 W/m^2K).

Roof: 300 mm mineral fibre, above a timber framework, with protected vapour barrier and steel-clad (U-value = 0.11 W/m^2K).

First floor: Precast concrete.

Stairs: Concrete.

Windows: Planned to be a mixture of aerogel rooflights and 3-glazed windows with argon and two sputtered low-emissivity coatings, in insulated wood frames (for latter, U-value = 0.8 W/m^2K).

Certain details still need research or development. A different technology may be used as an interim solution; namely, 2+1-glazed windows with 15 mm argon in the sealed unit, and three pyrolytic low-emissivity coatings, in aluminium-clad wood frames (measured U-value = 0.95 W/m^2K).

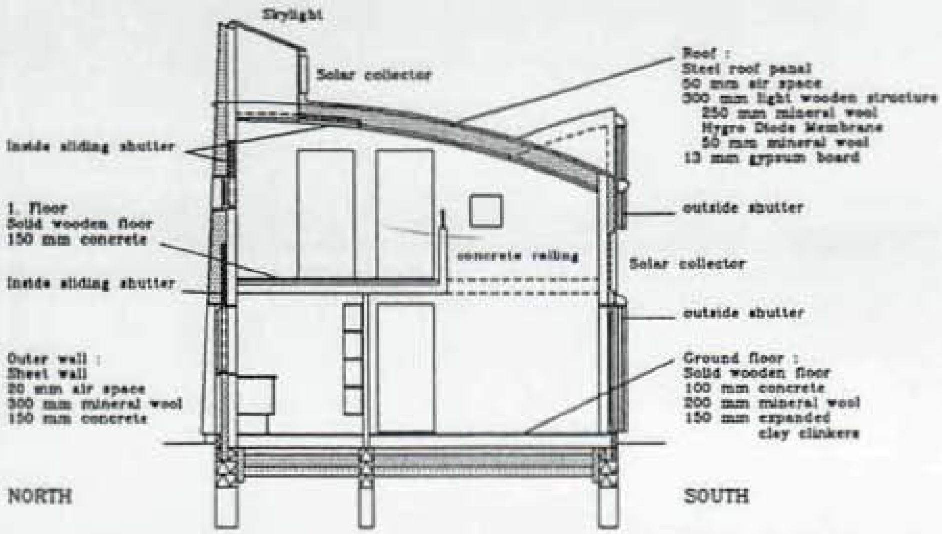
An exhaustive analysis was made of thermal bridging and airtightness. Relatively proven solutions to both were adopted.

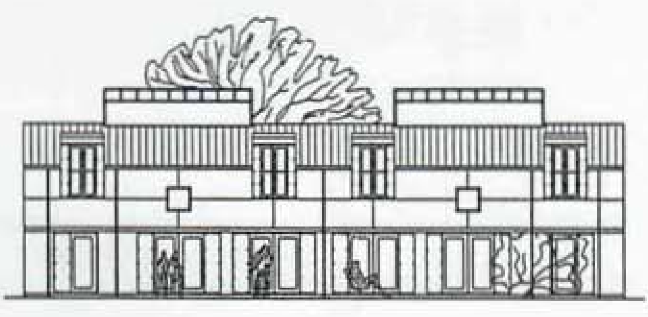
Air leakage: Based on previous Danish experience with similar construction, likely to be 0.4 - 0.6 ac/h at 50 Pa.

Ventilation: Low electricity mechanical ventilation and heat recovery system.

Energy use: Predicted < 60 kWh/m^2yr, of which space heating 15 kWh/m^2yr. Latter is 15% of figure for normal new Danish houses.

Costs: Not known. IEA Task 13 seeks to test experimental measures which are not yet proven or imminently on the market, but which show the promise of being important and valuable in the low-energy houses of the future.





overseas profile 9

TIMBER FRAME

Low-Energy House B, Hjortekaer, Denmark (1978)

Hjortekaer, Denmark. 1978. One in a development of six detached houses, all about 120 m². Organisation and underlying aims the same as House F (see profile 6).

Floor: Suspended timber with 300 mm mineral fibre (U-value = 0.10 W/m²K).

Walls: Timber frame with 250 mm mineral fibre, and brick-clad (U-value = 0.14 W/m²K).

Roof: Insulated with 400 mm mineral fibre on the attic floor (U-value = 0.09 W/m²K).

Windows: 3-glazed, in wood frames (U-value = 2.1 W/m²K).

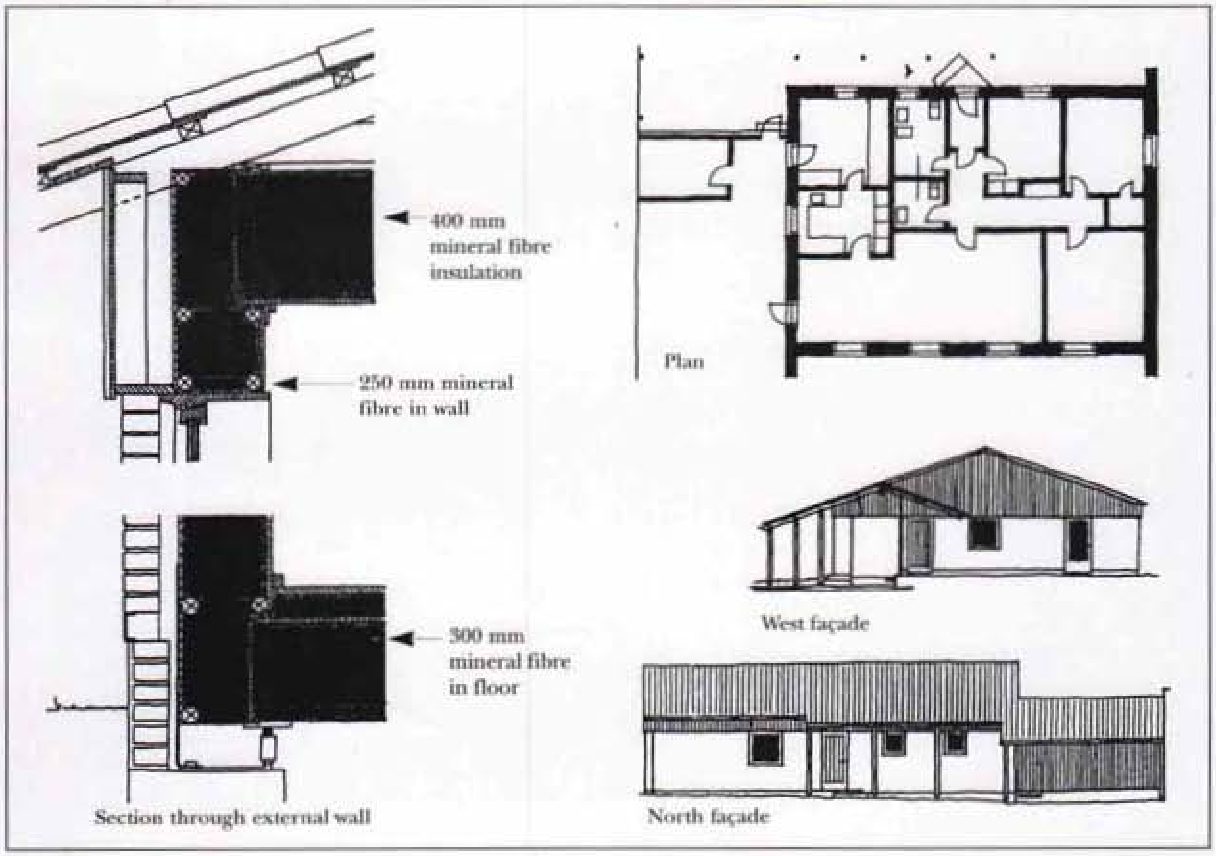
Air leakage: Tight polyethylene vapour barrier throughout. 0.02 ac/h in tracer gas measurements. 0.2 ac/h at 50 Pa in a blower door test.

Space and water heating: Electric heat pump feeding oversized radiators.

Ventilation: Mechanical ventilation and heat recovery.

Energy use: House B was within the 5000 kWh/year (42 kWh/m²yr) requirement. The measured heat loss was 75 W/K for a 123 m² dwelling.

Costs: Not known.



TIMBER FRAME, SITE-BUILT

Waterloo Region Green Home, Ontario, Canada (1992-95)

Two-storey 230 m² detached house. 'Raised bungalow', with a daylit basement within the heated volume. Joint venture by Enermodal Engineering Ltd, consulting engineers, and the Kitchener/Waterloo Home Builders' Association. The house form reflected the need to provide a basement, as the market demands, but in a way which is more economical and reduces the total consumption of building materials.

Basement walls: Novel coffered precast concrete elements, on pad foundations, to reduce the volume of concrete. Tanked externally and insulated with 75 mm high-density mineral fibre, plus land drains. Lined internally with 80-240 mm cellulose fibre (variable, owing to shape of concrete) within a timber frame.

Basement floor: 75 mm in-situ concrete slab, 50 mm high-density expanded polystyrene, 100 mm crushed glass waste.

Above-ground walls: High-density plasterboard, 235 mm cellulose fibre between I-beams. Space where timber floor meets walls filled with 150 mm in-situ polyurethane foam. Sheathed with 25 mm wood reinforced polyurethane foam and clad with boards made from recycled timber (U-value = 0.15 W/m²K).

Roof: 300 mm cellulose fibre between scissor trusses (U-value = 0.13 W/m²K).

Windows: 3-glazed with argon, two pyrolytic low-emissivity coatings, insulating spacers and insulated fibreglass frames (U-value = 1.0 W/m²K). Clerestory above centre of house provides plentiful daylighting.

External doors: Fibreglass-faced with 45 mm expanded polystyrene, glazed as for windows.

Air leakage: Well sealed polyethylene vapour barrier throughout. 0.8 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery but integrated with heating, as below.

Space and water heating: Gas-fired mid-efficiency warm air space heating system, with flue gas heat recovery via a small rock bed. Would be cheaper when commercialised than separate condensing appliance and air-to-air heat exchanger. Water heated by 6 m² of high efficiency flat-plate solar collectors, PV-powered pump and 450 litre storage tank, with gas backup. 70% solar fraction.

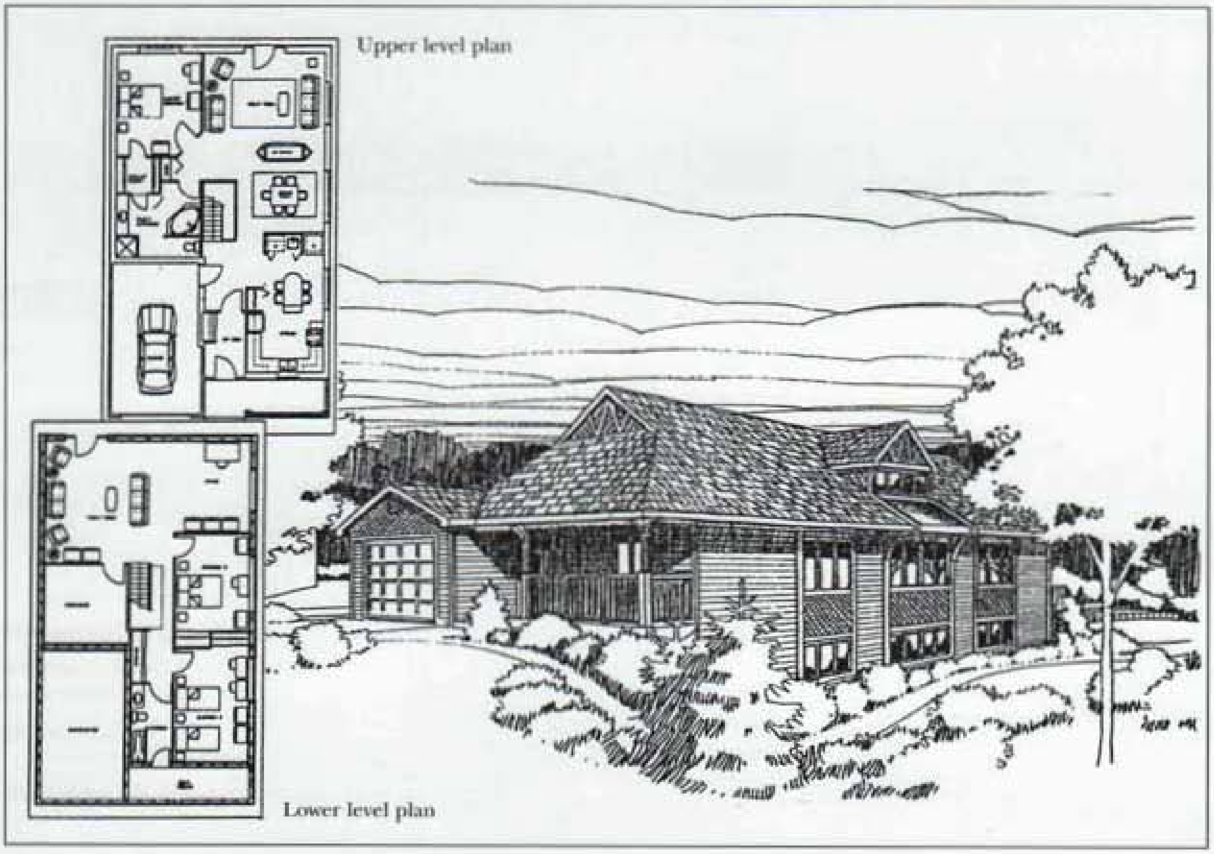
Cooking, lighting and electrical appliances: Energy efficient and CFC-free refrigerator. Balanced flue gas cooker. Balanced flue gas-fired clothes dryer with exhaust gas heat recovery.

Environmentally beneficial measures: Comprehensive efforts to use less environmentally damaging materials and produce less waste. All but a few kg of construction waste was recycled, compared to the normal 2.5 tonnes sent to landfill.

The basement is tanked with polybutylene not bitumen, which can leach into groundwater. The floor tiles are made from 70% waste glass. The bathroom has an ingenious internal borrowed light system, making use of scrap glass. The roof is clad with recycled steel, which has a lower environmental impact than asphalt shingles.

Energy use: Predicted 51 kWh/m²yr. Measured electricity use to date 20 kWh/m²yr.

Costs: Not known.



TIMBER FRAME, SITE-BUILT

Zero-Energy Timber frame House, Brunnadern, St Gallen, Switzerland (1991)

Detached two-storey 318 m^2 house on 'infill' site in small village. Privately funded.

Client and designer Hans Reudi Stutz, Architect.

Floor: 300 mm cellulose fibre, in a suspended timber floor above the cellar (U-value = 0.13 W/m^2K).

Above-ground walls: 300 mm cellulose fibre, timber-clad (U-value = 0.12 W/m^2K). Great care taken to fit a good air barrier and avoid heat loss due to wind penetration.

Roof: 350 mm cellulose fibre, placed in the slope of the roof (U-value = 0.11 W/m^2K).

Windows: Double glazed with argon and one sputtered very low-emissivity coating, in wood frames (U-value = 1.9 W/m^2K).

Air leakage: 0.17 ac/h at 50 Pa.

Ventilation: Exhaust-only system; performs the essential function of redistributing surplus solar heat from the south to the north side of the house.

Space and water heating: Warm air space heating via a heater battery in the ventilation ductwork, linked to the 6 m^3 solar heat store. Water heating also mostly solar. Stored solar heat keeps the house at 20°C most of the year; space heating is given priority over water heating. A woodstove is lit during periods of extreme cold or cloud, generally confined to December and January.

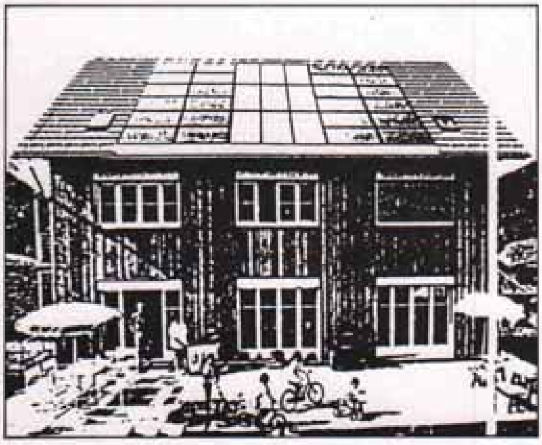
Lighting and electrical equipment: Induction cooker and advanced energy efficient lights and appliances.

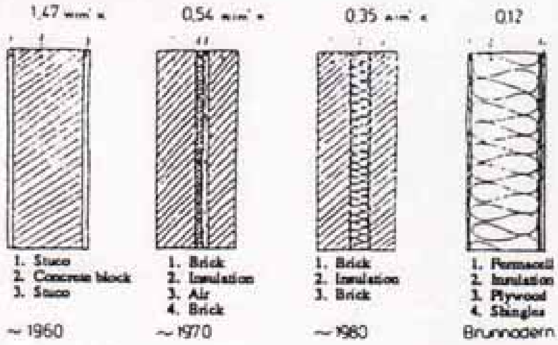
Other environmentally beneficial measures: Environmentally damaging materials were avoided in the construction of the house, as far as possible.

Electricity supply: 3 kW grid-connected PV system. Surplus electricity is sold back to the grid; deficits imported.

Energy use: Total measured backup fuel use; ie, wood for space and water heating, equivalent to 9 kWh/m^2yr. In a normal year, the PV system produces a quantity of electricity at least equal to the house's total electricity consumption.

Costs: Not known.





Wall construction improvements

overseas profile 12

TIMBER FRAME, SITE-BUILT

The Duncan House, Victoria, British Columbia, Canada (1983)

Detached 300 m² house. Flat site in low-density suburb; house faces due south.

Owner and designer Mr Robert Duncan. Privately funded. The project was an application in Canada's temperate zone of the 'superinsulated' housing technology developed in the 1970s in the much colder climate of central Canada.

Floors: Suspended timber, with 250 mm mineral fibre (U-value = 0.15 W/m²K).

Walls: Timber frame 'double wall' with inner row of 38 x 89 mm studs, 150 mm gap and outer row of staggered 38 x 63 mm studs, insulated with a total of 300 mm mineral fibre, sheathed with plywood, and timber-clad (U-value = 0.12 W/m²K).

Roof: 400 mm mineral fibre between trusses (U-value = 0.09 W/m²K). Clad with cedar shingles.

Windows and rooflights: (1) North - 3-glazed in wood frames (U-value = 2.1 W/m²K); (2) South - double glazed in wood frames (U-value = 2.8 W/m²K). Insulating shutters used in the coldest weather.

External doors: Steel-faced with 40 mm polyurethane foam (U-value = 0.65 W/m²K).

Air leakage: Well sealed polyethylene vapour barrier throughout house. 0.5 ac/h at 50 Pa. Tracer gas tests suggested 0.03 ac/h in winter conditions.

Ventilation: Mechanical ventilation and heat recovery.

Space heating system: A single thermostatically controlled and sub-metered electric radiator in the living room. It mostly operates at night when the outside temperature falls below 0°C. Local electricity is hydro-generated, so it was considered the most reasonable choice.

In this climate, the outside temperature falls on rare occasions to -8°C. Under such conditions, the ventilation system was found to distribute enough heat from a point source to maintain acceptable air temperatures throughout a 300 m² house. This made an internal heat distribution system unnecessary.

Water heating: 8 m² of flat-plate solar collectors and 300 litre storage tank; 70% solar fraction. Electric backup.

Lighting, appliances and ventilation: Moderately energy efficient. Limited by the technology of the time. Cold room provided below house, to reduce necessary size of refrigerator.

Total space heating energy use: Measured 1 kWh/m²yr with thermostat setting of 19°C.

Costs: Minimal overcost. The same size and shape of house had earlier been priced with normal insulation levels for this area and a full warm air heating system.

uk profile 1

MASONRY WITH CAVITY INSULATION

Wates House, Centre for Alternative Technology, Machynlleth (1976)

Architect: Peter Bond Associates, Richmond, Surrey.

Built before the term 'superinsulation' was recognised outside its North American home, the Wates House is still the most highly insulated house in the UK. In addition the design addresses the issues of energy for cooking, hot water and lighting.

Floor: Suspended timber floor with 450 mm of glass fibre insulation (U-value = 0.09 W/m^{2}K).

Walls: Aerated concrete block inner leaf, 450 mm built-in glass fibre, brick outer leaf. The outer wall is buttressed internally and only tied to the inner leaf at the buttresses (U-value = 0.075 W/m^{2}K).

Roof: Pitched roof insulated with 450 mm of glass fibre (U-value = 0.09 W/m^{2}K).

Glazing: 2 + 2-glazed windows both in timber frames (U-value = 1.5 W/m^{2}K). Only about 10% of floor area. Originally the outer window was fixed but subsequently both windows were openable.

Heating: The first heating design used an air-to-air heat pump using outside air and kitchen exhaust as a source. This fed a warm air heating system. Operating problems led this to be replaced by a propane gas circulator feeding one radiator.

The original design collected grey water from shower, sink and basins in an underground tank used as a source for another heat pump heating a 180 litre hot water cylinder. Again operating problems led to this being replaced by a conventional system.

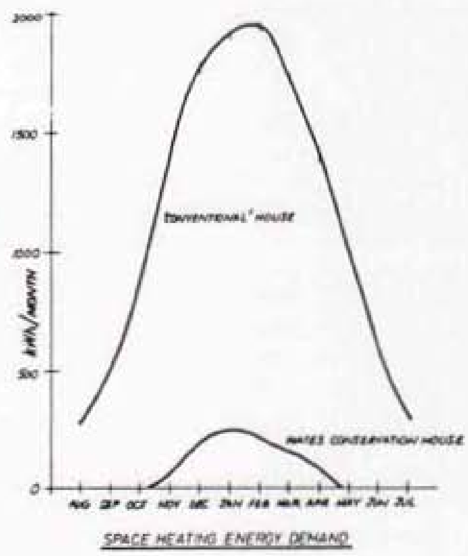
Air leakage: Not measured.

Water: Rainwater collected from the roof was designed to be filtered and used for everything except drinking.

Cooking: An electric oven was provided with 150 mm of glass fibre insulation. This halves the energy used for cooking.

Energy use: Not known.

Costs: Estimated overcost of £2000 has been paid back more than twice over since the house was built 18 years ago.



View of the wall construction, showing the 450 mm of insulation

uk profile 2

MASONRY WITH CAVITY INSULATION

Strawberry Hill Low-Energy Houses, Salford, Lancashire (1978 - 82)

Designers: Salford City Council in association with Department of Civil Engineering, University of Salford.

Semi-detached and terraced, public rented houses, typically 100 m². The first UK housing project to apply such high levels of insulation on this scale. About 200 such houses had been built by the early 1980s, when the local authority stopped building homes for rent. However, similar standards were later applied to sheltered housing at Peterloo Court, Salford and spec houses in Melton Mowbray, Leicestershire.

Ground Floor: Suspended concrete with 175 mm insulation (U-value = 0.2 W/m²K).

Walls: Cavity filled with 173 mm insulation, generally blown-in mineral fibre. One row of metal ties every storey, with piers in outer leaf (U-value = 0.2 W/m²K).

Roof: 200 mm mineral fibre on attic floor (U-value = 0.2 W/m²K).

First floors: Concrete. House high mass throughout, partly in an effort to deter vandalism.

Windows: 1+1 in wood frames (U-value = 2.6 W/m²K).

Air leakage: Not known.

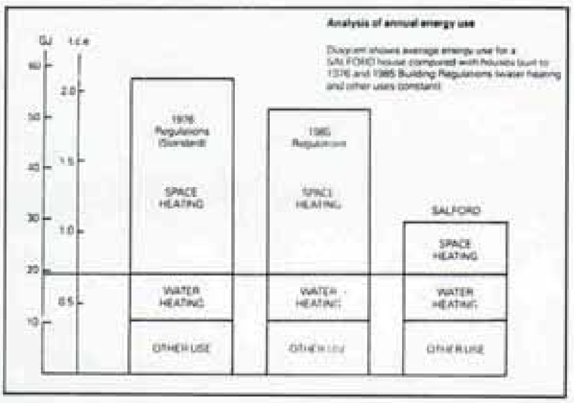
Ventilation: Manually controlled exhaust-only, no heat recovery.

Space and water heating: The first prototype houses had an electric heat pump or gas-fired boiler feeding underfloor pipes. Later houses obtained results nearly as good from a cheaper system, comprising through-the-wall gas convector heaters.

Lighting and electrical equipment: The project predated today's wide concern about electrical energy efficiency; no particular attempts were made to reduce these energy uses.

Energy use: For space heating, about 30 kWh/m²yr. Monitoring showed that the tenants maintained whole house temperatures of over 20°C from October to April. At the time, these comfort standards were unprecedentedly high.

Costs: In the range 4-7%. Multiple tenders were sought for schemes both with and without the package of novel measures, including the high thermal mass structure. The cost difference between concrete and timber suspended floors has since reduced. The overcost of the Irwell Valley Housing Association scheme was calculated to be 2-2.5%.



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uk profile 3

MASONRY WITH CAVITY INSULATION / EXTERNALLY INSULATED MASONRY

Reyburn Residence, Glentham Road, London SW13 (1984-92)

Client and architect: Stephen Reyburn.

Energy consultant: Energy Advisory Associates.

140 m² 2.5-storey house on small urban plot, totally filling the gap between adjacent houses.

Project conceived in 1984 but built slowly, over a long period, under the owner's supervision. Applied an integrated package of energy efficiency measures to masonry construction. Allowing for the differences in climate, the energy-related measures are similar to Danish low-energy houses of 1984. For architectural reasons, the house has a complex shape. This made it a challenge to detail to avoid thermal bridges.

Ground floor: Suspended concrete with 250 mm expanded polystyrene. (U-value = 0.15 W/m²K.) Thickness reflected Danish advice and allows for the influence of the underfloor heating.

Walls: (1) 60% - cavity brick/brick with 165 mm built- in mineral fibre batts and plastic ties (U-value = 0.21 W/m²K); (2) 40% - plaster, 102 mm single skin brickwork, 75 mm mineral fibre, 100 mm mineral fibre between 50 x 100 mm timber studs, timber cladding (U-value = 0.2 W/m²K); (3) Party wall adjacent to neighbouring house of same height - 50 mm mineral fibre in cavity wall (U-value = 0.55 W/m²K).

Roof: 250 mm mineral fibre between/below rafters (U-value = 0.18 W/m²K).

First and second floors: 300 mm in-situ concrete. Stairs: Respectively in-situ and precast concrete from the ground floor to the first floor and from the first to the second floor.

Windows: 3-glazed with argon and one sputtered low-emissivity coating, in wood frames (U-value = 1.5 W/m²K).

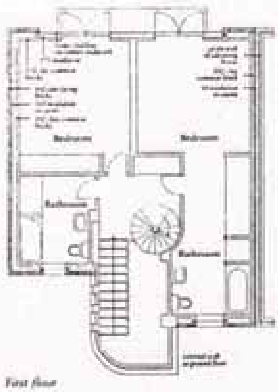
Air leakage: Given the performance of similarly constructed Swedish buildings, the target was 1 ac/h at 50 Pa, but it has not yet been measured.

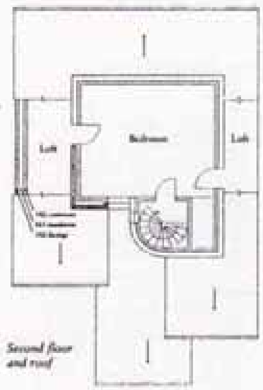
Ventilation: Mechanical ventilation and heat recovery.

Space and water heating: Gas-fired condensing boiler on the second floor, feeding an underfloor heating system and a mains-pressure hot water storage tank.

Energy use: See table below.

Costs: Not known.





Energy use: Measured 1991-1994

Energy carrier	Purpose	Usage kWh/m²yr
Gas	Space/water heating and cooking	90
Electricity	Ventilation, lighting and appliances	23
TOTAL		113

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uk profile 4

MASONRY WITH CAVITY INSULATION

Solar Courtyard Houses, Energy Park, Milton Keynes (1986)

Designers: Feilden Clegg Design, Bath, with Research in Buildings Group, University of Westminster.

Five single-storey houses built in a courtyard configuration, to allow for privacy, as well as solar gain through 'superglazed' south facade.

Floor: Ground-bearing concrete with 100 mm of expanded polystyrene under the slab, followed by internal screed (U-value = 0.29 W/m²K) or by 18 mm chipboard on a further 25 mm expanded polystyrene (U-value = 0.24 W/m²K).

Walls: Plaster, 100 mm lightweight concrete block, 100 mm polystyrene beads, brick outer leaf (U-value = 0.30 W/m²K).

Bedroom walls: Plaster, 100 mm lightweight concrete block, 100 mm expanded polystyrene, 75 mm air space, 4 mm fibre-reinforced cement sheets (U-value = 0.24 W/m²K).

Roofs: 160 mm glass fibre between rafters (U-value = 0.25 W/m²K).

Windows: 3+1-glazed with 12 mm argon and two sputtered low-emissivity coatings, low-emissivity louvre blind in non-sealed airspace (U-value = 0.9 W/m²K).

Some early cracking of the glazing was overcome, and the performance was good. However, the solar transmittance, at less than 50%, was less than expected.

Air leakage: 10.1 - 11.9 ac/h at 50 Pa. Higher than expected. Major leaks at joint between glazed wall and bedroom wing.

Heating: Gas-fired condensing boiler with two heating zones and double coil 210 litre HWS cylinder. High overall annual efficiencies, around 89%.

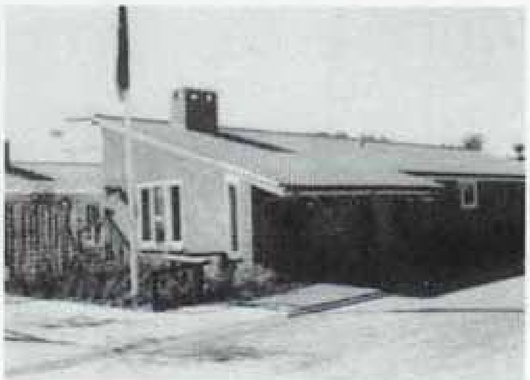
Ventilation: Mechanical ventilation and heat recovery.

Houses well liked by occupants. Heating and mechanical ventilation and heat recovery worked well. Good glazing U-values for the time, but solar transmittance needs to be improved.

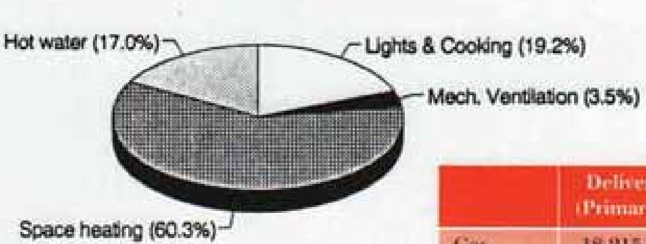
Energy use: Measured 1987.

Energy carrier	Purpose	Usage kWh/m²y
Gas	Space heating	112
Gas	Water heating	31
Gas and electricity	Cooking, lighting and appliances	35
Electricity	Ventilation	6
TOTAL		**184**

Costs: Experimental glazing £8000.



Annual Delivered Fuel



	Delivered kWh (Primary Energy)	Delivered GJ (Primary Energy)	Delivered kWh/m²
Gas	18 215 (19 490)	65.6 (70.8)	143
Electricity	5 331 (20 360)	19.2 (73.4)	42
Total	**23 546 (39 850)**	**84.8 (144.2)**	**185**

MASONRY WITH CAVITY INSULATION

The Longwood House, Huddersfield, West Yorkshire (1991- 92)

Builders: S Slator and W Butcher, Huddersfield.

Consultants: Drs R J Lowe and S Curwell, School of Architecture, Leeds Metropolitan University.

107 m^2 two-storey house built on a steep south-facing slope, with north entrance on the first floor. Speculatively-built. It dried out before it was sold, so the gas consumption listed below should be a good indication of long term performance. The design closely matches the local vernacular; eg it has a natural stone outer leaf.

Floor: 100 mm expanded polystyrene below a reinforced concrete slab.

External above-ground walls: Dense concrete block inner leaf, 150 mm blown mineral fibre with plastic ties, stone outer leaf (U-value = 0.21 W/m^2K). Clinker concrete block inner leaf above attic floor level.

External below-ground walls: Similar to above ground but with 150 mm expanded polystyrene (U-value = 0.21 W/m^2K).

Retaining wall: as cavity walls, plus 100 mm reinforced concrete externally.

Roof: 300 mm cellulose fibre on attic floor (U-value = 0.13 W/m^2K). Interlocking concrete tiles. No roof vapour barrier, but masonry partitions were built after ceiling was finished. Cellulose fibre is also known to contribute to airtightness.

First floor: Timber. Tried to reduce air leakage at junction of floor and external wall, using polyurethane foam.

Windows: Air-filled double glazing with one pyrolytic low-emissivity coating (U-value = 2.4 W/m^2K). The cavities are closed with plasterboard. There are separate inner and outer lintels.

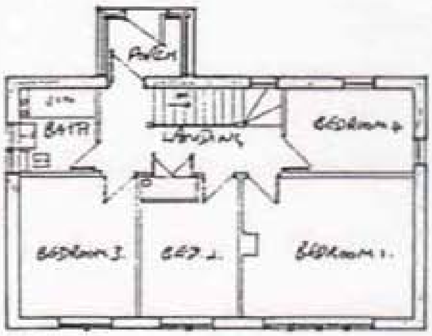
Air leakage: 3 ac/h at 50 Pa. Unlike Charlbury (Profile 6), there were many small leaks, not a few individual large ones, so remedial work was not attempted.

Ventilation: Passive stack for background ventilation. Timed exhaust ventilation from 'wet' rooms.

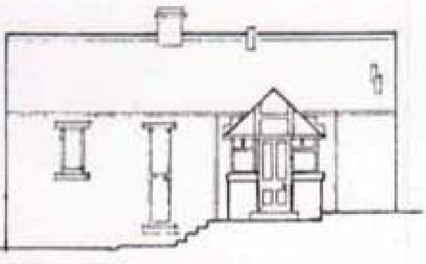
Heating: Gas-fired condensing boiler and radiator in most rooms. Chimney and woodstove.

Energy use: Measured 80 kWh/m^2yr, of which gas 59 kWh/m^2yr and electricity 21 kWh/m^2yr.

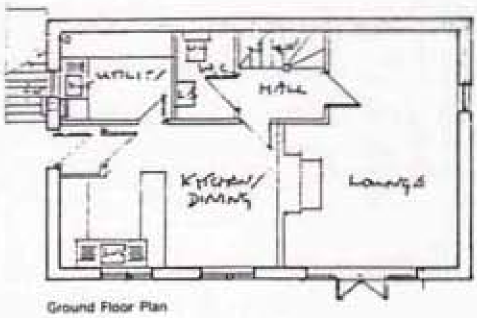
Costs: The overcost is thought to be roughly £3000.



First Floor Plan



North Elevation



Ground Floor Plan

uk profile 6

MASONRY WITH CAVITY INSULATION

Lower Watts House, Charlbury, Oxfordshire (1992)

Clients: Stephen Andrews and Liz Reason, Ilex Associates, Oxford.

Architect: David Woods Architects, Witney.

Energy consultant: Energy Advisory Associates.

290 m² detached house with double garage. Within the town's conservation area, surrounded by medieval stone buildings. Orientation is not ideal; the site has good solar exposure to south-west but high trees to the south and south-east.

Floor: Suspended concrete beam-and-block, inherited with foundations of existing building. 150 mm expanded polystyrene above the deck and below the screed (U-value = 0.22 W/m²K).

Walls: Cavity with 150 mm built-in mineral fibre batts, plastic ties and 150 mm Cotswold stone outer leaf (U-value = 0.22 W/m²K).

Roof: Plasterboard, 50 mm mineral fibre, protected vapour barrier, 200 mm mineral fibre between rafters, plus 50 mm expanded polystyrene sheathing (U-value = 0.12 W/m²K).

First floor: Concrete.

Second floor: Timber; attempt to seal it to wall, but fairly difficult to build.

Windows: 2+1-glazed with argon and one sputtered low-emissivity coating, in wood frames (U-value = 1.35 W/m²K). Rooflights: 3-glazed with argon and one sputtered low-emissivity coating (U-value = 1.7 W/m²K).

External doors: Insulated with 40 mm polyurethane foam (U-value = 0.65 W/m²K).

Air leakage: Tight polyethylene vapour barrier throughout roof. Initially 3.6 ac/h at 50 Pa. Estimated to have fallen to 2 ac/h at 50 Pa by blocking the five major leaks. Fairly complex shape, so reasonably low by UK standards, although target had been 1 ac/h.

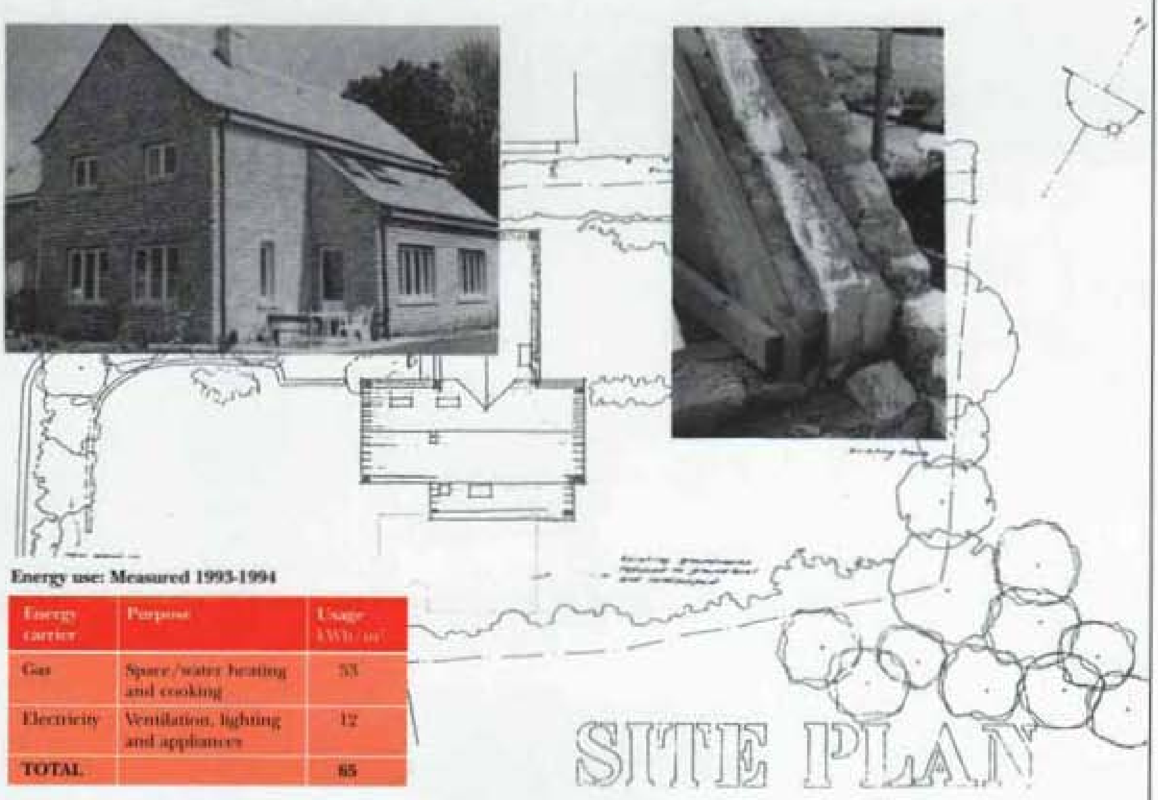
Heating: Gas-fired condensing boiler serving steel column radiators, mains-pressure hot water storage tank. Woodstove and chimney, with independent air supply.

Ventilation: Mechanical ventilation and heat recovery using counterflow, not cross-flow, heat exchanger.

Lighting and electrical equipment: Energy efficient, where possible.

Energy use: Estimated about 70 kWh/m²yr. Measured over heating season 1993-94 (see table below).

Costs: £550 per m², the same as other custom-built houses in the area. Large savings on the number of heat emitters contributed to this.



Energy use: Measured 1993-1994

Energy carrier	Purpose	Usage kWh/m²
Gas	Space/water heating and cooking	53
Electricity	Ventilation, lighting and appliances	12
TOTAL		65

MASONRY WITH CAVITY INSULATION

Cresswell Road Houses, Darnall, Sheffield (1992-93)

Client: North Sheffield Housing Association.

Architects: Robert and Brenda Vale, Southwell, Nottinghamshire.

Quantity surveyor: Gordon Hall Grayson and Co.

Structural engineer: E J Allott and Associates.

Two 88 m² semi-detached superinsulated houses built with no additional cost.

Floor: Suspended concrete above 150 mm expanded polystyrene.

Walls: Aerated concrete block, 150 mm built-in mineral fibre batts, clay brick (U-value = 0.21 W/m²K).

Roof: 400 mm cellulose fibre (U-value = 0.08 W/m²K).

First Floors: Timber.

Windows: 3-glazed with argon and one sputtered low-emissivity coating, in softwood frames (U-value = 1.5 W/m²K).

External doors: Timber with 40 mm polyurethane foam (U-value = 1.0 W/m²K).

Air leakage: Not known.

Ventilation: Passive stack with humidity sensors.

Space and water heating: Gas-fired condensing combination boiler, feeding oversized radiators.

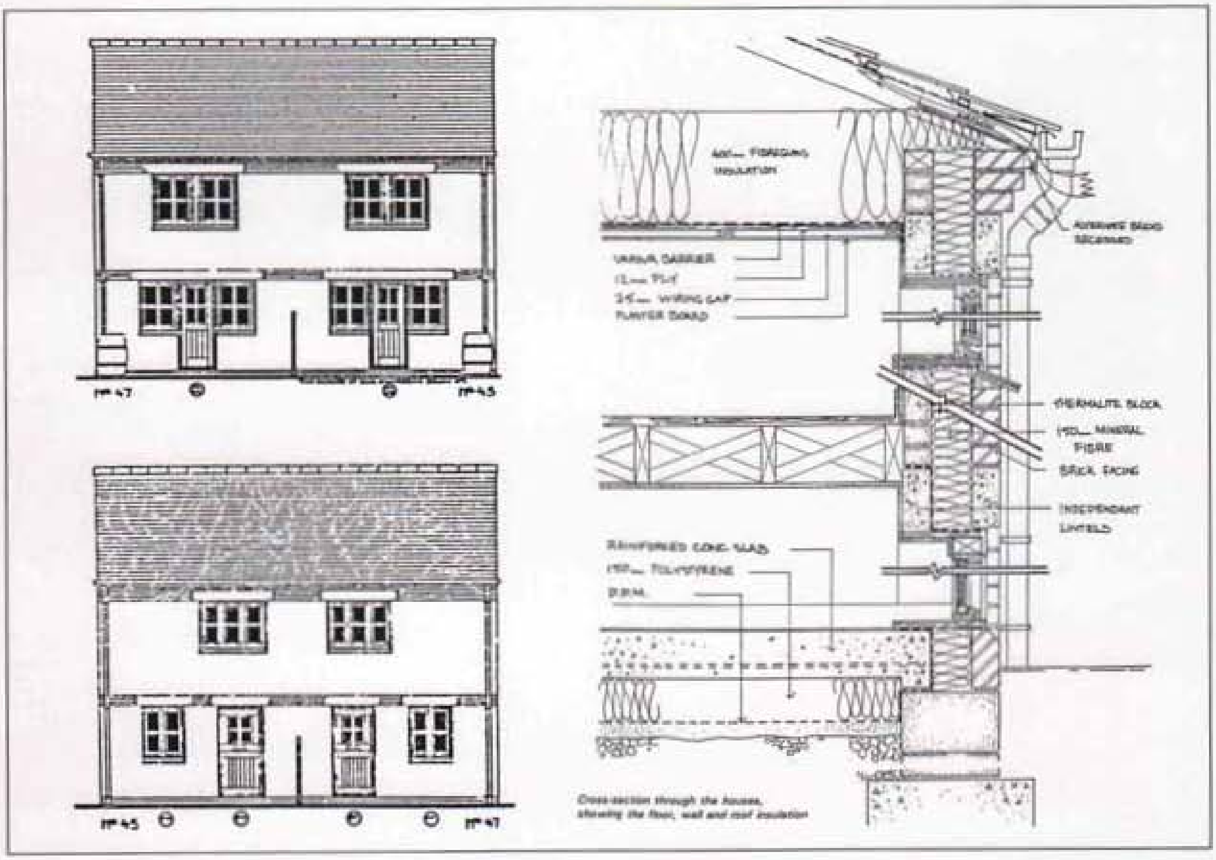
Lighting: Fluorescent. Energy efficient appliances could not be provided because of social housing rules.

Other environmentally beneficial measures: Rainwater capture, water efficient WCs. External landscaping designed to avoid run-off and minimise disturbance to the site's water balance. The designers tried to use materials with a reduced environmental impact, both local and global; eg the downstairs floor covering is linoleum, not PVC, the first floor is clad with softwood, not chipboard, and the gutters are timber, not PVC.

Energy use: Measured 1993-1994

Energy carrier	Purpose	Usage kWh/m²/a
Gas	Space/water heating and cooking	108
Electricity	Lighting and appliances	26
TOTAL		134

Costs: Below the Housing Corporation budget.



Cross-section through the houses, showing the floor, wall and roof insulation

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MASONRY WITH CAVITY INSULATION

Ash Tree Cottage, Westbury, Buckinghamshire (1993-94)

Architect: Currivan Haynes, Stroud.

198 m² 1.5-storey house. Custom-built. Designed in keeping with the local style. Back of house faces somewhat east of south.

Floor: 55 mm screed and underfloor heating, 19 mm plywood, 200 mm mineral fibre between suspended timber joists on 600 mm centres, ventilated airspace (U-value = 0.18 W/m²K).

Walls: 100 mm aerated concrete block, 150 mm mineral fibre with plastic ties, aerated concrete block outer leaf, render (U-value = 0.19 W/m²K).

50 + 100 mm mineral fibre between 50 x 50 and 100 x 50 mm timber studs, timber-clad (U-value = 0.3 W/m²K).

Roof: Mostly standard trusses.
2 x 100 mm mineral fibre between and above joists, to reduce thermal bridging (U-value = 0.21 W/m²K);
2 x 100 mm mineral fibre between rafters and 100 mm between internal cross-battens (U-value = 0.23 W/m²K);
100 mm mineral fibre to roof of dormers, between 50 x 100 mm rafters (U-value = 0.43 W/m²K).
Slate-covered.

First floor: Timber.

Windows: Double glazed, with 6 mm air and one pyrolytic low-emissivity coating. Frames made from local timber (U-value = 2.6 W/m²K). 54% on South wall. Double oak lintels at window openings. Plywood sub-frame utilised to close cavity with little thermal bridging and at low cost.

External doors: Solid wood. Some glazed as for windows.

Air leakage: Not measured. Polyethylene vapour barrier throughout roof.

Ventilation: Passive stack.

Heating: Oil-fired boiler. Underfloor heating downstairs and radiators upstairs. Small solid fuel stove also. 4 m² solar collectors for water heating.

Lighting: Energy efficient fluorescent.

Energy use: Calculated 98 kWh/m²yr.

Costs: Total building cost was £ 750/m².

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MASONRY WITH CAVITY INSULATION

Family Housing Association, Brixton, London (1993)

Client: Family Housing Association.

Architect: Moran Architects, London SE24.

Consultants: Brenda and Robert Vale, University of Nottingham.

Revisions to thermal design and monitoring by Research in Building, University of Westminster under a THERMIE grant.

Nine 72 m² terraced houses plus five control houses. Superficially a masonry version of Two Mile Ash. Most construction details are more conventional than the other masonry houses in this report.

Floor: Suspended concrete with 50 - 125 mm expanded polystyrene elements between prestressed concrete T-beams, forming permanent shuttering for 150 mm in-situ concrete (U-value = 0.28 W/m²K).

Walls: Lightweight concrete block inner leaf, 150 mm blown-in mineral fibre with metal ties, brick outer leaf (U-value = 0.22 W/m²K).

Roof: 300mm mineral fibre on attic floor (U-value = 0.13 W/m²K).

Windows: 3-glazed with argon and one sputtered low-emissivity coating, in wood frames (U-value = 1.5 W/m²K).

Air leakage: A tracer gas test in mild weather gave air leakage of < 0.1 ac/h. However, hard to compare with pressure test results from other schemes.

Ventilation: Mechanical ventilation and heat recovery.

Heating system: Gas-fired condensing boiler with radiators and mains-pressure hot water storage system. Space heating energy use measured 1993-94, 35 kWh/m²yr.

Space heating energy is increased by the tenants' decision to maintain an extremely high internal air temperature, namely, over 22°C from October to May. This appears to reflect the low marginal cost of comfort in these houses. It occurs despite the effect of the warm internal surfaces, which should make well insulated and draught proof houses comfortable at a lower air temperature than normal houses.

Total energy use: Not yet known.

Costs: The measures were superimposed on an existing design-and-build contract, and the overcost was 8%. A study by a quantity surveyor gave an overcost for the items actually fitted of £3000, or 6%.

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MASONRY WITH CAVITY INSULATION

The Autonomous Urban House, Southwell, Nottinghamshire (1993)

Owners and designers: Robert and Brenda Vale.

2.5-storey house, 169 m^2 excluding unheated cellar. Aim for autonomy in all principal services. The house ridge follows a north-south axis in line with the existing street and the PV system on a pergola in the garden.

A two-storey conservatory is attached to the west-facing, garden side of the house.

Basement floor: 300 mm concrete raft foundation.

Basement walls: 2 x 100 mm aerated concrete blocks as permanent shuttering to reinforced concrete.

Ground floor: Concrete with 50 mm cellulose fibre sprayed on soffit (U-value = 0.6 W/m^{2}K).

Walls: 100 mm dense block, 250 mm built-in mineral fibre batts and plastic ties, brick (U-value = 0.14 W/m^{2}K).

Roof: Internal timber cladding, I-beam rafters with 500 mm cellulose fibre, clay pantiles (U-value = 0.07 W/m^{2}K).

Windows: 3-glazed with krypton and two sputtered low-emissivity coatings, in wood frames (U-value = 1.15 W/m^{2}K). Conservatory double glazed with argon and one low-emissivity coating (U-value = 2.1 W/m^{2}K). Rooflights - as for conservatory glazing.

Air leakage: Not known.

Ventilation: Through-the-wall mechanical ventilation and heat recovery units in 'wet' rooms, taking preheated air from the conservatory.

Water heating: Initial design solar with electric backup; later design electric heat pump.

Space heating: Passive solar with 4 kW backup woodstove. It was calculated that the backup space heat input, in order to maintain a minimum air temperature of 18°C, would be 3 kWh/m^{2}yr.

Electricity supply: 2.2 kW grid-connected PV system.

Water supply: Stored and filtered rainwater, collected from the roof via copper rainwater goods.

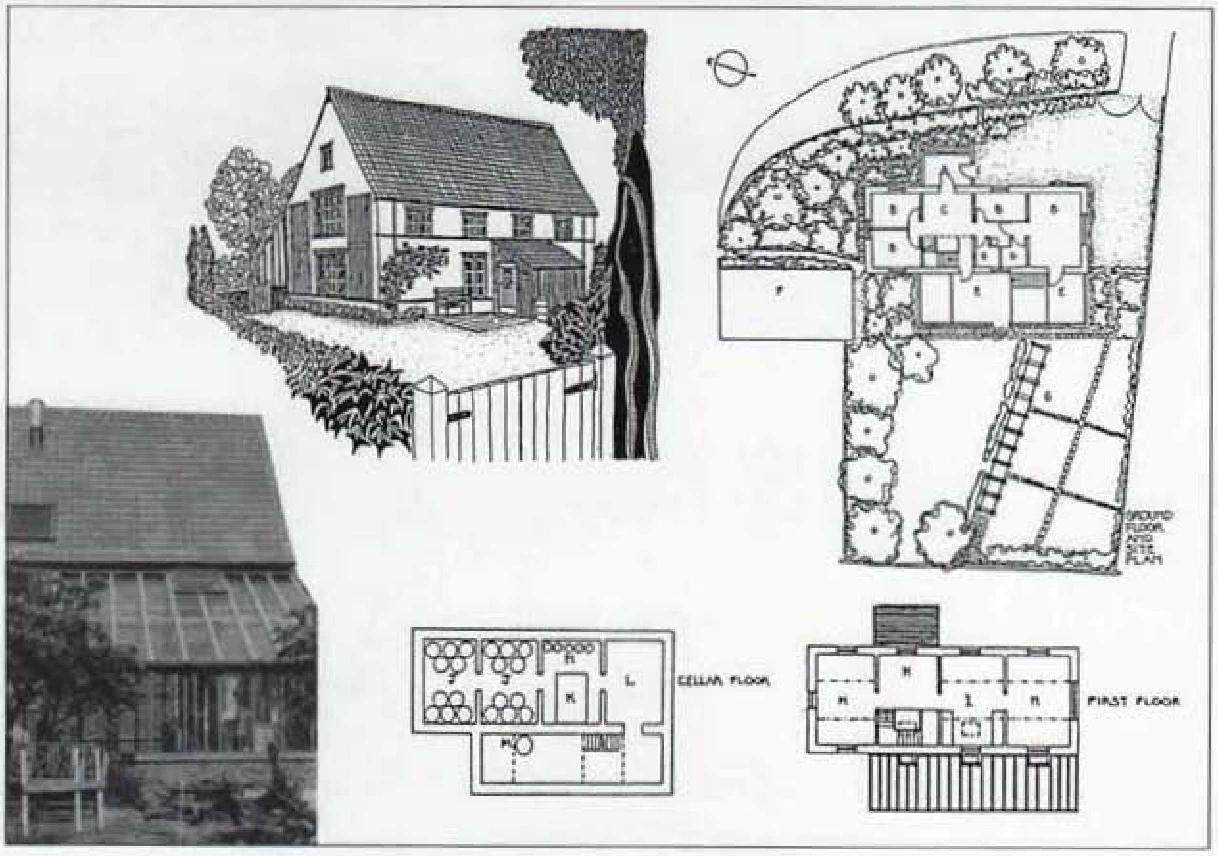
Sewage treatment: Composting toilet. Soakaway for grey water.

Environmentally beneficial measures: The selection of materials resulted from a careful assessment of their embodied energy, transport energy and implications on the internal environment and health of the occupants.

Energy use: Excluding wood backup. Before installation of the solar thermal and PV system, measured electricity use was about 17 kWh/m^{2}yr.

Costs: Total building cost was £880/m^2 excluding unheated basement, £540/m^2 including basement and all ancillary spaces.

NB see Section 4 for 12 more of these houses.



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MASONRY WITH CAVITY INSULATION

Roaf Residence, Blandford Avenue, North Oxford (1994)

Client: Dr Susan Roaf, Lecturer, School of Architecture, Oxford Brookes University.

Architect: David Woods Architects, Witney.

260 m² detached house, 2.5-storey and very compact in shape. Rear of house faces 15° E of S down long, thin site.

Floor: 22 mm softwood boarding, airspace, 150 mm concrete slab-on-ground, dpm, 150 mm expanded polystyrene, 200 mm blinded hardcore (U-value = 0.2 W/m²K).

Walls: 150 mm dense block, 150 mm built-in mineral fibre batts and plastic ties, 100 mm clay brick (U-value = 0.22 W/m²K).

Roof: Plasterboard, 50 mm mineral fibre between cross-battens, 200 mm mineral fibre between rafters, 50 mm expanded polystyrene sheathing, battens and concrete tiles (U-value = 0.12 W/m²K). South slope clad by PV panels and solar thermal collectors instead of tiles.

First floor: Concrete beam-and-block. Soffit plastered to expose the thermal mass and also increase heat transfer from heated rooms to unheated bedrooms.

Second floor: Timber.

Windows: (1) Adjacent to buffer spaces - air-filled double glazed with one sputtered low-emissivity coating (U-value = 2.3 W/m²K); (2) Elsewhere - 2+1-glazed (U-value = 1.7 W/m²K). Both in wood frames.

Rooflights: Double glazed with insulating shutters.

Efforts to reduce thermal bridging and air leakage, as for Lower Watts House (Profile No 6). A double-glazed conservatory on the south wall, and a porch on the north wall, serve as air-lock entrances.

Ventilation: Passive stack, with extract fans in all 'wet' rooms and trickle vents in other windows.

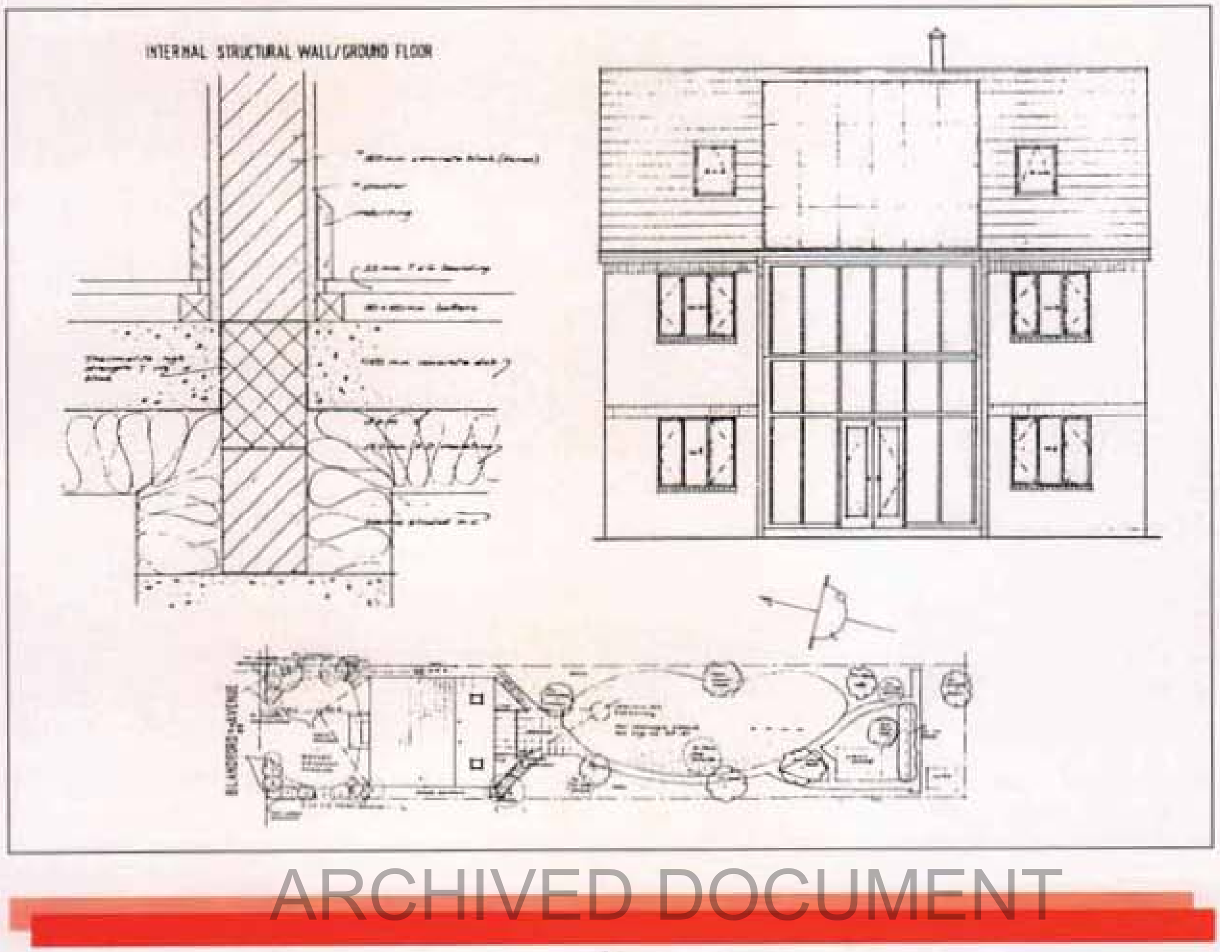
Space and water heating: Gas-fired condensing boiler and five radiators for space and water heating, plus a ceramic woodstove on ground floor. Large solar water heating system, using high efficiency flat plate collectors, with gas backup.

Lighting and electrical equipment: Energy efficient fluorescent lights, appliances within limits of UK market.

Electricity supply: Grid-connected PV roof. Numerous difficulties being encountered in its installation.

Energy use: Not yet known.

Costs: £800/m² building costs excluding land.



MASONRY WITH CAVITY INSULATION

Mill Orchard, Paunton, Bishops Frome, Herefordshire (1992-94)

Clients: Dick and Jill Fowler. Also providing much of the construction management.

Designer: Robert Scott, the Scott Williams Partnership, Chartered Surveyors, Bromyard.

Structural engineer: Chris Mattingly, Hereford.

Energy consultant: Energy Advisory Associates.

250 m² new farmhouse. Site in open countryside. Centre of house has large 'winter garden' above two-storey dining room. Designed and built 1994; short time-scale, as it had taken two years to obtain planning permission.

Floor: 100 mm concrete ground bearing slab, dpm, 100 mm expanded polystyrene, 150 mm gravel and hardcore (U-value = 0.25 W/m²K).

Walls: Plaster, dense concrete block, 150 mm built-in mineral fibre batts, using plastic cavity wall ties, faced with nominal 200 mm local stone (U-value = 0.22 W/m²K).

Roof: 300 mm mineral fibre between composite I-beam rafters on 600 mm centres, to reduce thermal bridging (U-value = 0.12 W/m²K).

First and second floors: Concrete beam-and-block.

Windows: 2+1-glazed with argon and one pyrolytic low-emissivity coating, in wood frames (U-value = 1.4 W/m²K).

External doors:
(1) South - glazed as windows;
(2) North - insulated with 40 mm polyurethane foam (U-value = 0.65 W/m²K).

Winter garden glazing: Sloping glass - 3-glazed with argon and two sputtered low-emissivity coatings (U-value = 1.0 W/m²K). Aim to admit maximum visible light but reduce winter heat loss and reduce inward solar heat gains, especially in summer.

Vertical glass – as other windows.

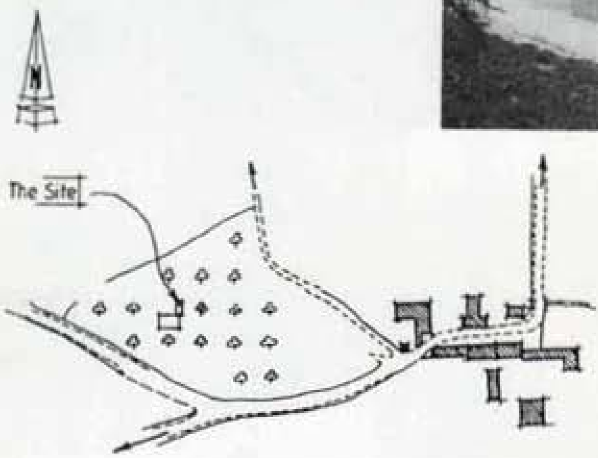
Air leakage: Not yet known.

Ventilation: Mechanical ventilation and heat recovery.

Heating: Aga and woodstove with independent air supplies. Oil-fired space heating system omitted to reduce budget, but may be installed later if necessary.

Energy use: Based on oil heating, was expected to use about 80 kWh/m²yr.

Costs: Not yet known. Constructed on a direct labour basis for about £300 per m². This low budget is, however, typical of houses in the area.



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MASONRY WITH CAVITY INSULATION

Oasis Of Peace, Porthmadog, Gwynnedd, Wales (1994)

Client: Catholic Peace and Marriage Centre.

Architect: David Lea Architects, Ogoronwy, Penrhyndeudraeth.

Small one-bedroom house. Part of a larger development. Uses high levels of insulation and thermal mass.

Floor: Softwood boarding, vapour barrier, 150 mm cellulose fibre between 195 mm joists on 400 mm centres, ventilated airspace, concrete ground cover (U-value = 0.18 W/m²K).

Walls: Lime plaster, 190 mm dense concrete block, 200 mm built-in mineral fibre batts with plastic ties, 100 mm clay brick, 30 mm external render (U-value = 0.17 W/m²K).

Roof: (1) Domed area with 50 x 75 mm joists on 400 mm centres, 350 mm cellulose fibre, rafters and purlins; (2) Flat area with 400 mm cellulose fibre (U-value = 0.08 W/m²K). All slate-clad.

Windows: Double glazed with argon and one sputtered low-emissivity coating, of Danish origin (U-value = 2.3 W/m²K). Located in plane of thermal insulation, and softwood sub-frame used to close cavity to reduce thermal bridging. Fixed lights direct-glazed into sub-frame.

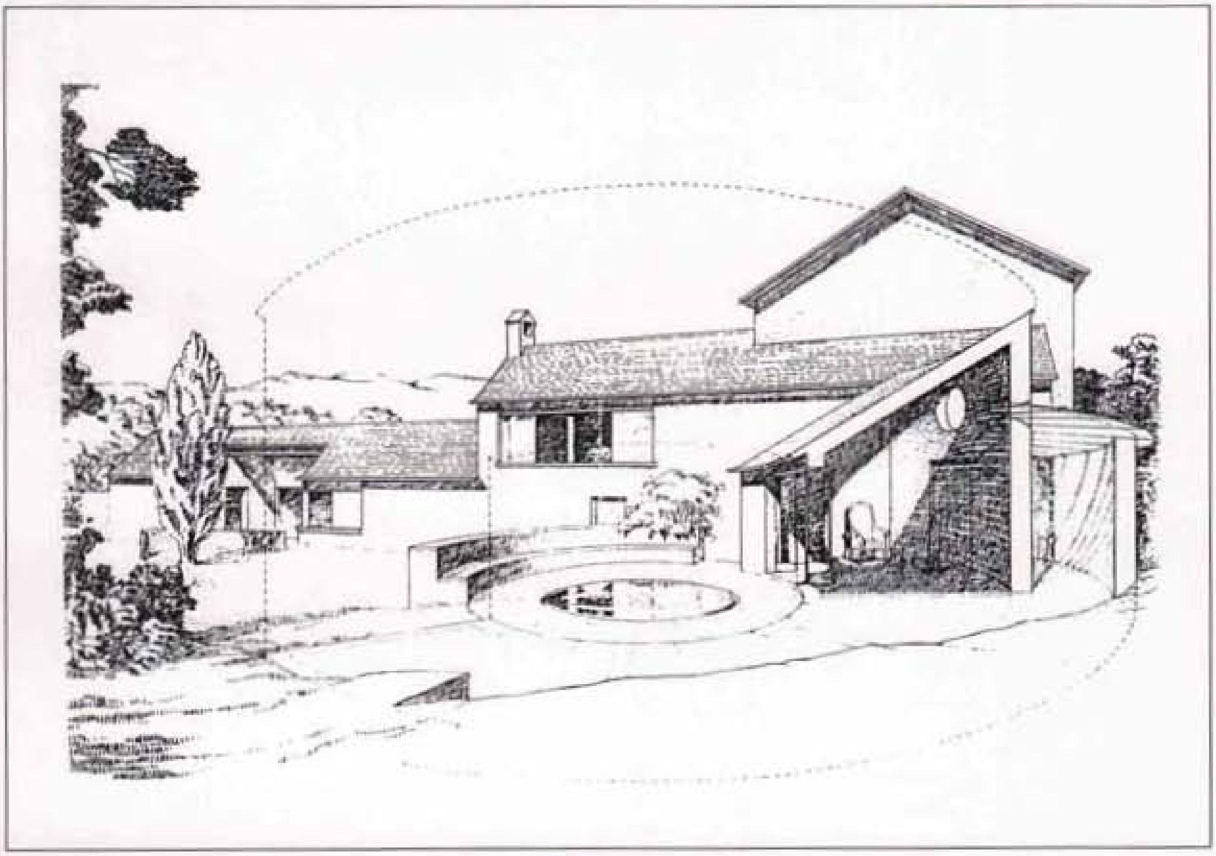
Air leakage: Not known. Internal vapour barrier in roof.

Ventilation: Passive stack plus trickle ventilators in all window frames.

Space and water heating system: Small gas-fired condensing boiler and radiators.

Energy use: Not known.

Costs: Approximately £660/m².



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MASONRY WITH CAVITY INSULATION

The Cowe House, Old Leake Commonside, Boston, Lincolnshire (1992-94)

Clients: Mr John Cowe and Miss Kathleen Cowe.

Architect: Roger Wright, Lincoln.

Energy consultant: Energy Advisory Associates.

220 m² two-storey detached house. Flat site. Rear of house faces due south. Construction began September 1994.

Floor: Concrete slab-on-ground, 150 mm expanded polystyrene, dpm, hardcore (U-value = 0.2 W/m²K).

Walls: 100 mm dense concrete block, 200 mm built-in mineral fibre batts and plastic ties, 100 mm clay brick (U-value = 0.18 W/m²K).

Roof: 300 mm cellulose fibre between plywood-webbed I-beam rafters (U-value = 0.12 W/m²K).

First floor: Concrete.

Windows: 2+1-glazed with argon and one pyrolytic low-emissivity coating (U-value = 1.4 W/m²K).

Large conservatory; double glazed with one low-emissivity coating. The original intention was to make it part of the living space, but it will now be treated as outside the heated volume. While it will be comfortable and suitable for living space for the majority of the year, this will not necessarily be so in the middle of winter.

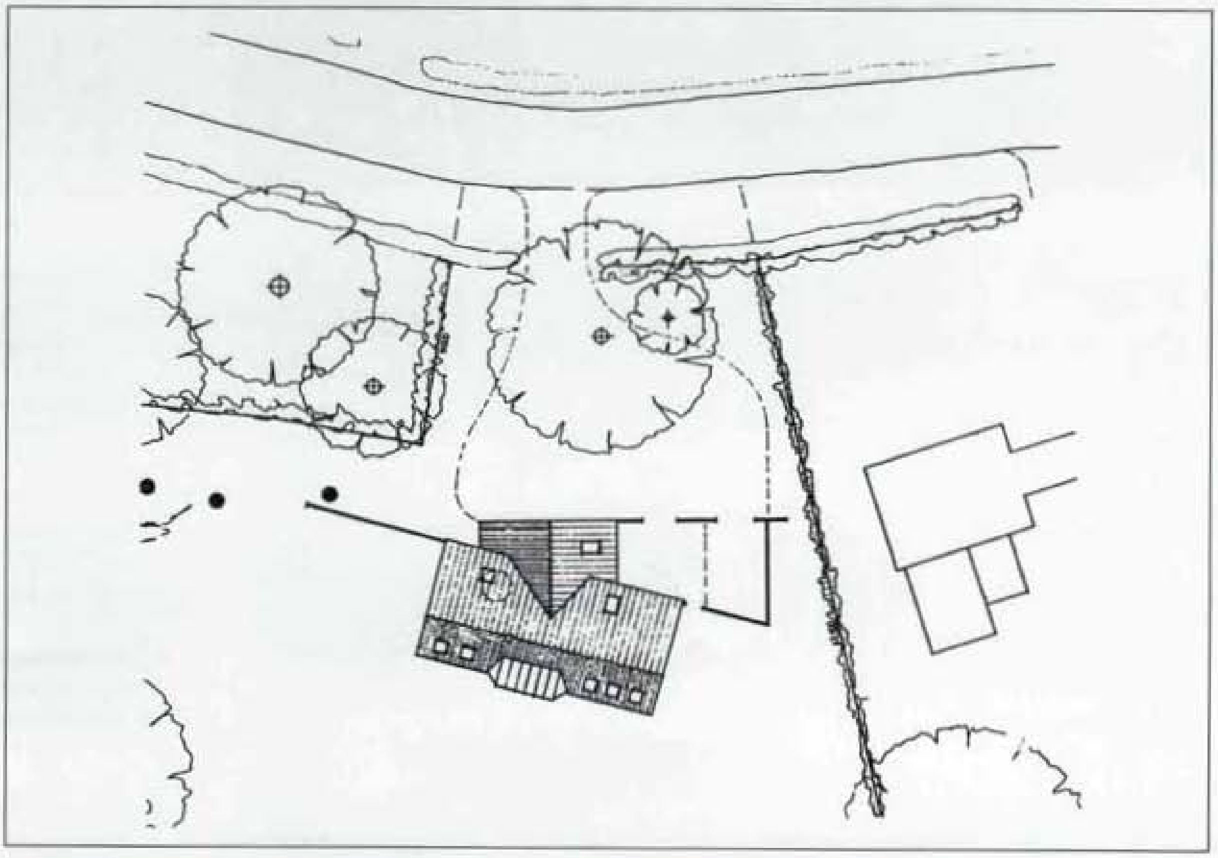
Air leakage: Sealed polyethylene vapour barrier in roof. Target is 1 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery.

Space and water heating: LPG-fired condensing boiler, feeding radiators and mains-pressure storage tank.

Energy use: Calculated 80 kWh/m²yr excluding workshop.

Costs: Not known.



MASONRY WITH CAVITY INSULATION

Auton Croft, Saffron Walden (1994-95)

Client: Hastoe Housing Association.

Architect: MEPK Architects, Bedford.

Consulting engineers: Merz Orchard, London.

A THERMIE project using a roof sunspace as preheat for mechanical ventilation and heat recovery. 15 houses with 6 control houses. Its sister project at Milton Keynes has 20 houses with 18 control houses.

Floors: Suspended concrete beams with expanded polystyrene elements as permanent shuttering (U-value = 0.21 W/m^{2}K).

Walls: Dense block, cavity with 200 mm blown mineral fibre and vertical twist-type steel ties on 750 mm centres, brick (U-value = 0.19 W/m^{2}K).

Roof: Insulated on attic floor with 100 mm glass fibre between + 100 mm above joists (U-value = 0.18 W/m^{2}K).

Windows: Double glazed, air-filled, one sputtered low- emissivity coating (U-value = 2.4 W/m^{2}K). Six houses proposed with U-value = 1.0 W/m^{2}K.

External doors: Insulated (U-value = 0.8 W/m^{2}K).

Space heating: Gas condensing boiler in roof space plant rooms serves terraces of three or four houses. The boiler is fitted with a Boiler Energy Manager. Each house has radiators with TRVs and a programmer which controls a 2-port valve on the heating flow. Heat consumption by each house is measured by a volumetric flow meter.

Ventilation: A solar roof space collector is used to preheat air for the mechanical ventilation and heat recovery system. The preheated air passes over a heat exchanger, where it picks up heat from the exhaust air from each house. Warmed air is passed from the heat exchanger to the living rooms and bedrooms in each house.

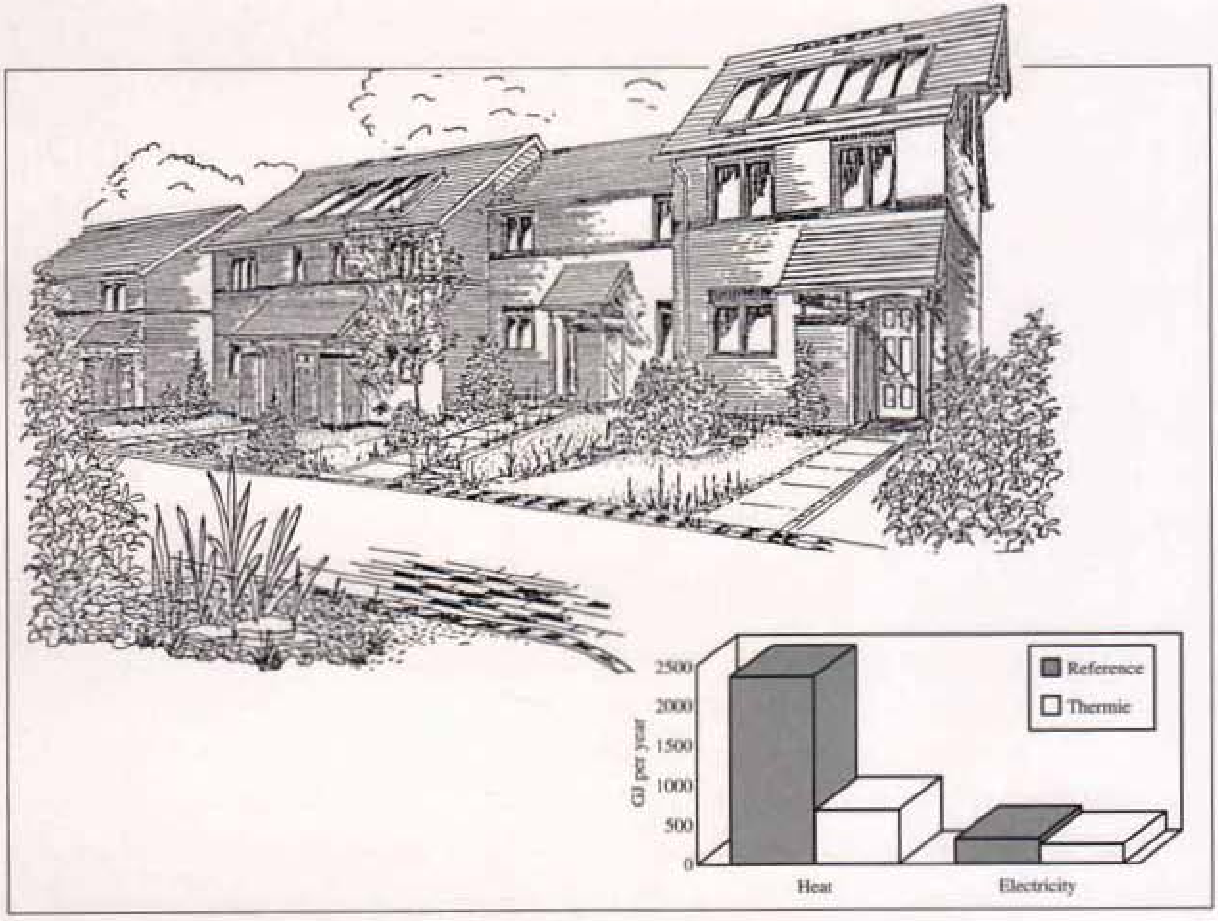
Water heating: Flat plate solar water heaters. The solar-heated water is fed to the lower coil in a dual coil 210 litre highly-insulated cylinder in each house. The top coil is fed from the condensing boiler circuit again with a 2-port valve controlled by the programmer. Hot water from the unvented cylinder is blended before passing to low-flow taps and shower heads.

Lighting: Fluorescent.

Energy use: Predicted 87 kWh/m^{2}yr, of which space heating around 13 kWh/m^{2}yr. Estimated annual energy savings: 60%.

Costs: Overcost estimated £11 000/house.

NB Other similar Thermie projects in Gateshead, Hull and Swansea reported in Section 4.



MASONRY WITH CAVITY INSULATION

Rockingham House Redevelopment, Bristol (1995/6)

Client: Bristol City Council.

Architect: Feilden Clegg Design, Bath.

A THERMIE funded project, involves the demolition of one large L-shaped 1950s slab block and its replacement by 44 houses and flats. Sizes vary from 44 m² to 74 m².

Floors: Solid concrete with 75 mm insulation below screed (U-value = 0.2 - 0.24 W/m²K).

Walls: Plaster, dense concrete block, 200 mm mineral fibre with plastic ties, brick (U-value = 0.17 W/m²K).

Roofs: Pitched roofs with 225 mm cellulose insulation (U-value = 0.14 W/m²K).

Glazing: Double glazed with argon and one low-emissivity coating, in softwood frames (U-value = 2.1 W/m²K).

Air leakage: To be tested and must conform to a standard of 3 m³/hr.m² at 25 Pa. The phrasing of this requirement closely follows the current wording of the 1989 Swedish building code, but it appears to be required at a lower pressure of 25 instead of 50 Pa.

Space heating: Central gas condensing boilers will serve a central heat store which in turn will serve thermal stores in each house. The thermal stores in the houses will serve radiators and hot taps via a coil in the store.

Ventilation: Passive stack ventilation with humidity controlled extract.

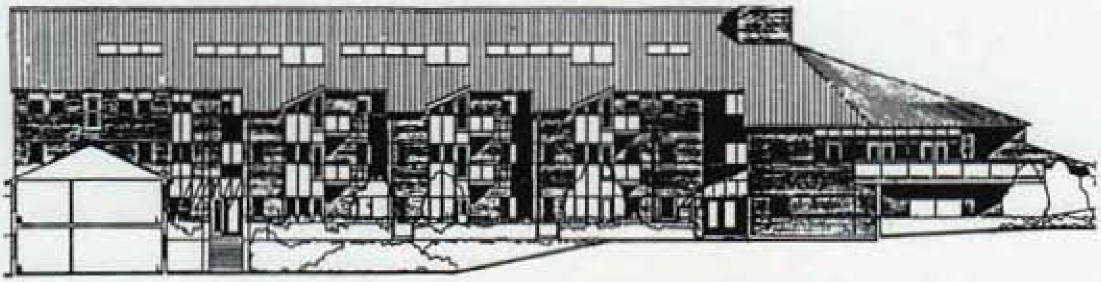
Hot water: Preheating of supply to the communal laundry by solar panels and a waste water heater heat recovery unit is to be evaluated.

Lighting: In communal areas, will be fluorescent, switched by passive infra-red controls and daylight sensors. In the dwellings, fluorescent to be fitted in the lounge, kitchen and halls.

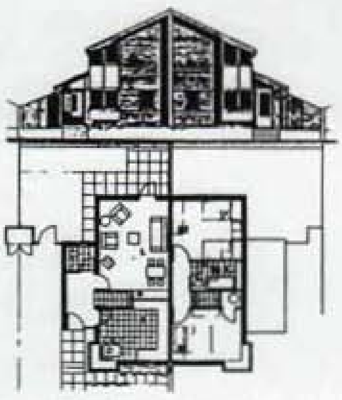
Environmentally beneficial measures: There are plans to carry out an embodied energy study. Another interesting design brief concerns the recycling of demolition rubble from the existing buildings.

Energy use: Not known.

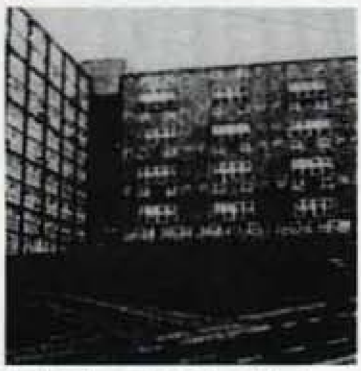
Costs: Not known.



Courtyard elevation of sheltered housing.



Semi-detached houses along Top Road.



Windsor house to be demolished

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EXTERNALLY INSULATED MASONRY

Midsummer Cottages, Futureworld, Milton Keynes (1993-94)

Client: Milton Keynes Housing Association.

Architect: Levitt Bernstein Associates Ltd., London.

Services engineers: Fulcrum Engineering Partnership, London.

Contribution to the thermal design by Energy Advisory Associates.

Five social housing units, from 65 to 90 m². Intended as a prototype for 21st century housing.

Floor: Concrete slab with 100 mm expanded polystyrene (U-value = 0.25 W/m²K).

Walls: Plaster, 215 mm brick, 150 mm rigid mineral fibre, render (U-value = 0.25 W/m²K).

Roof: 250 mm mineral fibre, between and below rafters (U-value = 0.18 W/m²K).

First floor: Timber.

Windows: 3-glazed, in wood frames.

Air leakage: Not known. Sealed polyethylene vapour barrier throughout roof structure.

Major efforts to reduce thermal bridging.

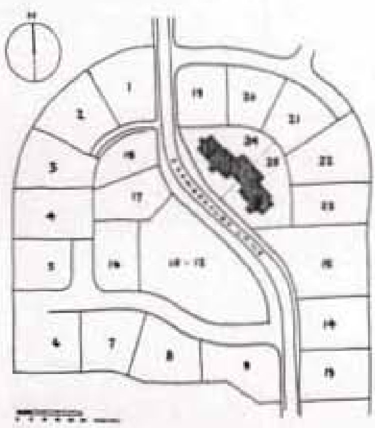
Heating: Gas-fired condensing boiler; one panel radiator per room.

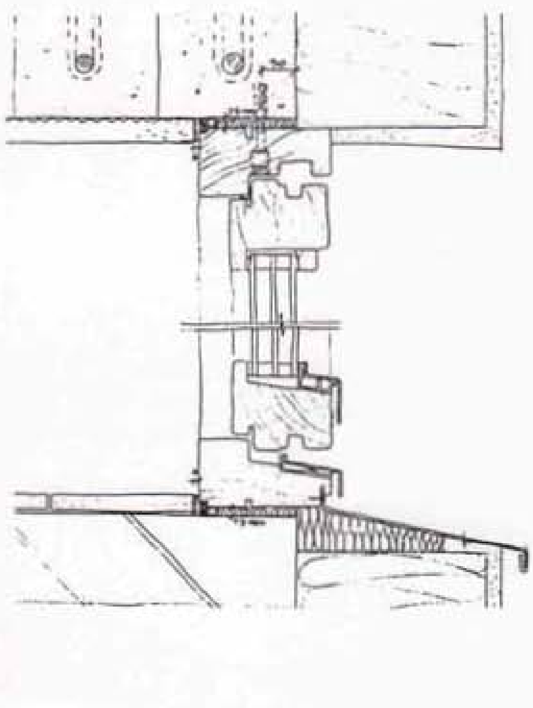
Ventilation: One house has a limited earth tube ventilation system.

Lighting: Energy efficient. Housing association rules precluded the provision of other electrical equipment, so energy efficiency could not be influenced.

Energy use: Not yet known. It is thought that the need to build these masonry houses in only four months may have compromised their energy performance.

Costs: About £650/m², in part because of the very short time-scale. Overcost about 9%.





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EXTERNALLY INSULATED MASONRY

Kendal, Cumbria (1993-95)

Client: Two Castles Housing Association, Carlisle.

Architect: Nichol Armstrong Lowe, Penrith.

Ten flats, each of 50-65 m^2. Detailed design and tendering not to begin until 1995.

Ground floors: Concrete slab with 150 mm expanded polystyrene.

Walls: (1) N/E/W - 420 mm. Thin-jointed aerated blocks externally insulated with 50 mm mineral fibre, lime render on mesh (U-value = 0.22 W/m^{2}K); (2): South - Timber frame with 150 mm cellulose fibre, timber-clad (U-value = 0.29 W/m^{2}K).

Roof: Deep trusses with 400 mm sheep's wool (U-value = 0.11 W/m^{2}K).

Upper floors: Concrete.

Windows: To be made from local timber to a Norwegian design, under licence.

Air leakage: Target < 4 ac/h at 50 Pa.

Ventilation: Passive stack.

Space heating: Gas-fired warm air.

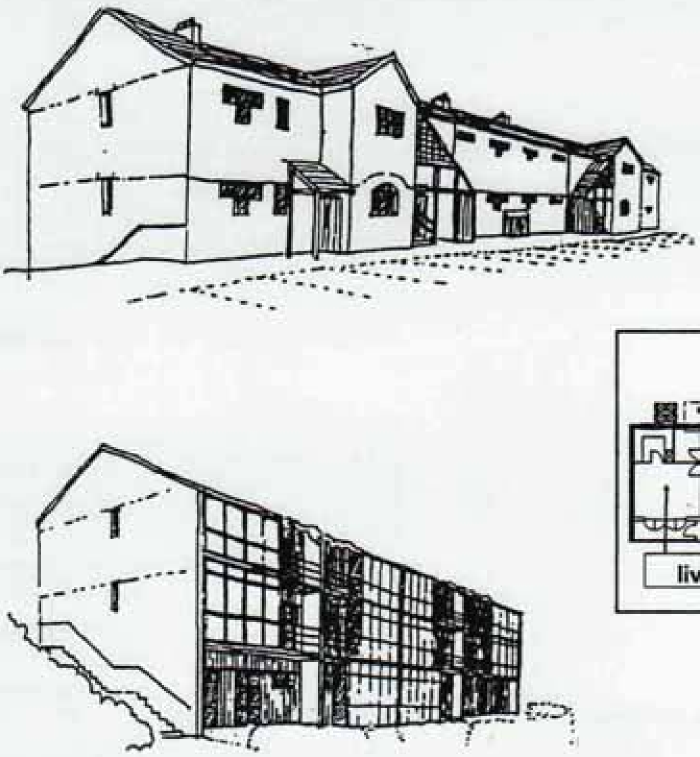
Lighting and electrical equipment: Energy efficient lighting. No control over other electricity uses or cooking.

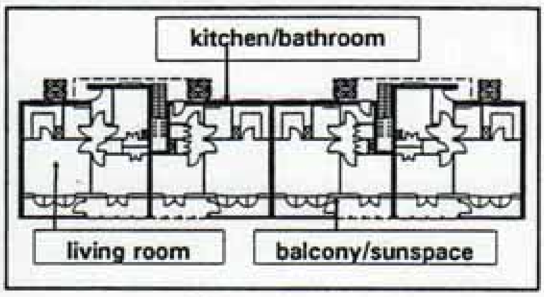
Environmentally beneficial measures: Numerou[illegible]g natural slate roof with copper rather than lead flashings.

NB The construction method for this project was under review at the time this profile was written.

Energy use: Not known.

Costs: Expected to be within the Housing Corporation budget, but no more information until funding allocated.





ground floor plan

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EXTERNALLY INSULATED RAMMED EARTH

Elmsett Ecological House, East Suffolk (1993-95)

Client: Mrs Jill Grimwade.

Architect: Roy Grimwade Architects, Colchester.

Energy consultant: Energy Advisory Associates.

140 m² cottage on infill plot in small village. Design stage, will be built in 1995. Designed to reach zero space heating energy with minimal backup, and close to zero net CO_2 emissions.

Floor: Modified slab-on-ground with 225 mm insulation (U-value = 0.13 W/m²K).

Walls: Plaster, 250 mm rammed earth, 350 mm cellulose fibre in timber support structure, air barrier, render on mesh (U-value = 0.10 W/m²K).

Roof: 450 mm cellulose fibre between built-up I-beams, clad with clay pantiles (U-value = 0.08 W/m²K).

First floor: Timber.

Windows: Novel construction being developed, as for Lyonshall (no.23), in wood frames (U-value = 0.8 W/m²K).

Great care being taken to design out thermal bridges and reduce air leakage near to the values for Danish, Swiss and German 'zero-energy' houses.

Air leakage: Target 0.4 ac/h at 50 Pa.

Space heating: Small woodstove provided to assist with drying-out and for aesthetic reasons thereafter.

Water heating: Solar with LPG backup. No gas connection.

Ventilation: Mechanical ventilation and heat recovery system designed for high sensible heat efficiency and low electricity use.

Water: Rainwater treatment and storage. Reed bed for sewage treatment.

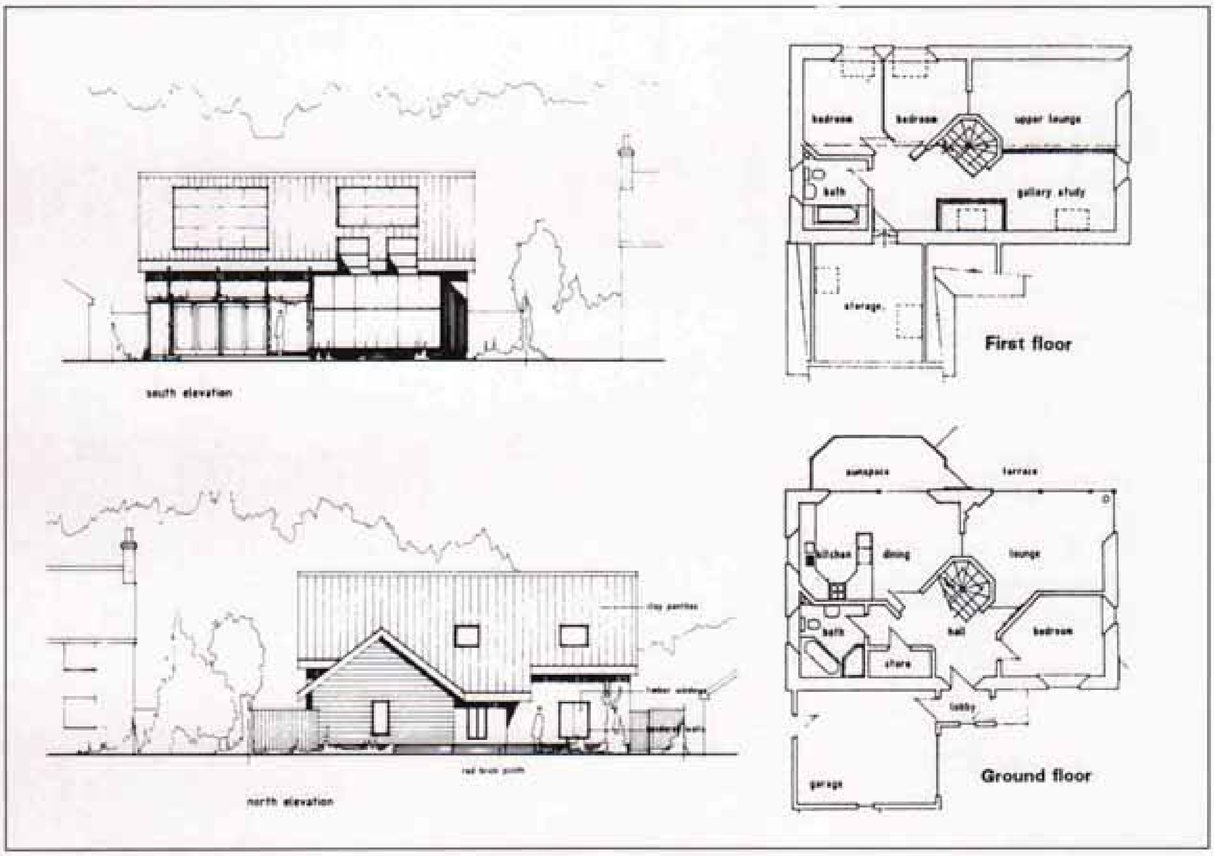
Lighting and electrical appliances: Designed to be of 'world class' energy efficiency.

Electricity supply: 3 kW PV roof-mounted system. Allowing for PV exports, projected electricity use is negative and the project could repay its CO_2 debt, mainly attributable to the construction energy, over a 50 year period.

Environmentally beneficial measures: Materials which 'offgas' noxious substances and have a high local environmental impact, or have a high impact in the global sense, eg HCFCs, will be avoided. Limited afforestation on site will compensate for the small on-site use of fossil fuel.

Energy use: Calculated 25 kWh/m²yr including solar.

Costs: Not known.



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INTERNALLY INSULATED MASONRY

Low-Energy House, Kirkhill, Inverness, Scotland (1990)

Owner and designer: Brian Smith.

Owner-designed-and-built four-bedroom house with interesting wall construction and direct gain passive solar.

Floor: Chipboard floating on 100 mm expanded polystyrene, 100 mm concrete slab (U-value = 0.23 W/m^2K).

Walls: Plasterboard, vapour barrier, 60 mm mineral fibre between non-load-bearing timber studwork, 50 mm mineral fibre batt in space next to wall, 200 mm ultra-lightweight aerated concrete block, external render (U-value = 0.21 W/m^2K).

Roof: Plasterboard, 200 mm mineral fibre between rafters, 50 mm ventilated air space, tiles on sarking felt (U-value = 0.21 W/m^2K).

Windows: Double glazed with 20 mm argon and one low-emissivity coating, in wood frames (U-value = 2.0 W/m^2K).

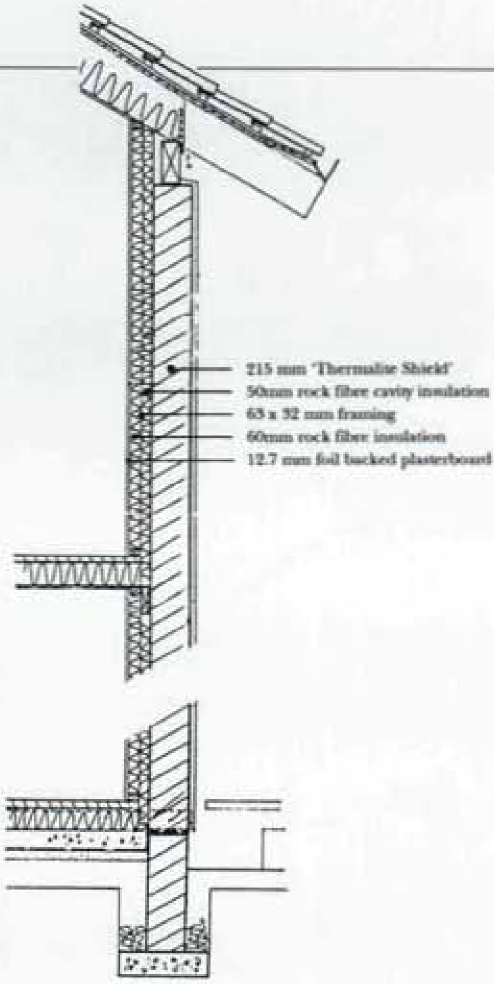
Air leakage: Owner reports problems with air disturbing the roof insulation on windy days.

Ventilation: Mechanical ventilation and heat recovery.

Space heating: Electric resistance ceiling panels run on cheap-rate electricity, supplemented by wood-burning stove.

Energy use: Not known.

Costs: Not known.



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IN-SITU CONCRETE

Warmhome 200, Glengormley, Newtownabbey, Northern Ireland (1988)

Designer: Joe Kerr for Springvale Expanded Polystyrene Ltd.

210 m² four-bed dormer bungalow. Walls built with permanent expanded polystyrene shuttering and in-situ concrete, developed by a Northern Irish firm, Springvale Polystyrene Ltd. South-facing living rooms with conservatory.

Remarkably low measured energy consumption considering the thermal insulation levels.

Floor: Suspended beam-and-block with 150 mm expanded polystyrene infill blocks, vapour barrier and 18 mm chipboard (U-value = 0.24 W/m²K).

Walls: Plasterboard, 50 mm expanded polystyrene permanent shuttering, 160 mm in-situ concrete, 60 mm expanded polystyrene shuttering, painted render on stainless steel mesh (U-value = 0.28 W/m²K).

Roof: Plasterboard, rafter-and-panel high performance roof system comprising insulated plywood box section rafters on 1220 mm centres with 200 mm plywood /expanded polystyrene laminated panels, tiled and felted externally (U-value = 0.19 W/m²K).

Windows: Low-emissivity air-filled double glazing, in hardwood frames (U-value = 2.4 W/m²K).

Air leakage: No pressure test carried out.

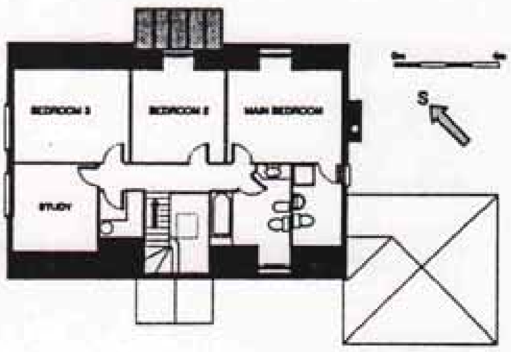
Space and water heating: Off-peak electric storage boiler with radiators in each room and underfloor heating in conservatory. Energy management system controls temperatures in each room as well as optimum start/stop.

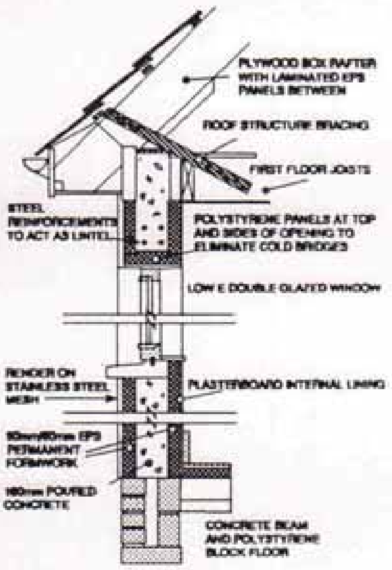
Ventilation: Mechanical ventilation and heat recovery.

Energy use: Measured electricity use 81 kWh/m²yr, of which space heating 45 kWh/m²yr.

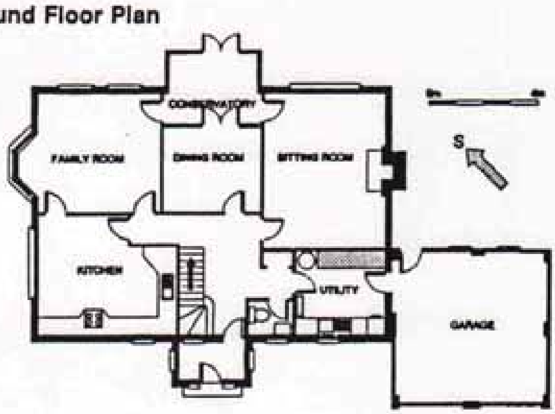
Costs: Not known.

First Floor Plan





Ground Floor Plan



IN-SITU CONCRETE

Embleton Residence, Twyford, Berkshire (1994-95)

Clients: Mr and Mrs M E Embleton.

Architect: Francis Sedgman, Twyford.

Energy consultant: Energy Advisory Associates.

Bungalow, about 160 m² in floor area, including heated basement below approximately 50% of the floor area. Being built on a semi-direct labour basis, in order to obtain a higher quality building at a given cost. Example of use of basement to enable the development of a house on a 'backland' urban site.

Basement floor: Concrete raft overlying 80 mm extruded polystyrene. The structure rests completely upon thermal insulation (U-value = 0.25 W/m²K).

Ground floor: Similar to basement, plus 50 mm expanded polystyrene below the screed of the underfloor heating system (U-value = 0.2 W/m²K).

Basement walls: 160 mm in-situ concrete in permanent shuttering of 2 x 50 mm expanded polystyrene, plus a further 75 mm mineral fibre externally, giving a total of 175 mm insulation (reducing to 125 mm at floor intersections) (U-value = 0.23 W/m²K). Weep holes and land drains.

External above-ground walls: (1) Normally in-situ concrete in 2 x 50 mm expanded polystyrene as permanent shuttering, extra 75 mm expanded polystyrene externally, 25 mm residual cavity, giving total 175 mm insulation (125 mm at floor intersections), externally rendered or brick-clad (U-value = 0.21 W/m²K). (2) Small curved section - 100 mm mineral fibre batts externally, giving total 200 mm insulation (reducing to 150 mm at floor intersections), brick-clad (U-value = 0.19 W/m²K).

Roof: 50+120 mm extruded polystyrene, between and above rafters, sealed at seams to form vapour barrier (U-value = 0.18). Roof space not to be used now but may be eventually.

Windows: 2+1-glazed with argon, semi-insulating spacer in sealed unit and one sputtered low-emissivity coating (U-value = 1.25).

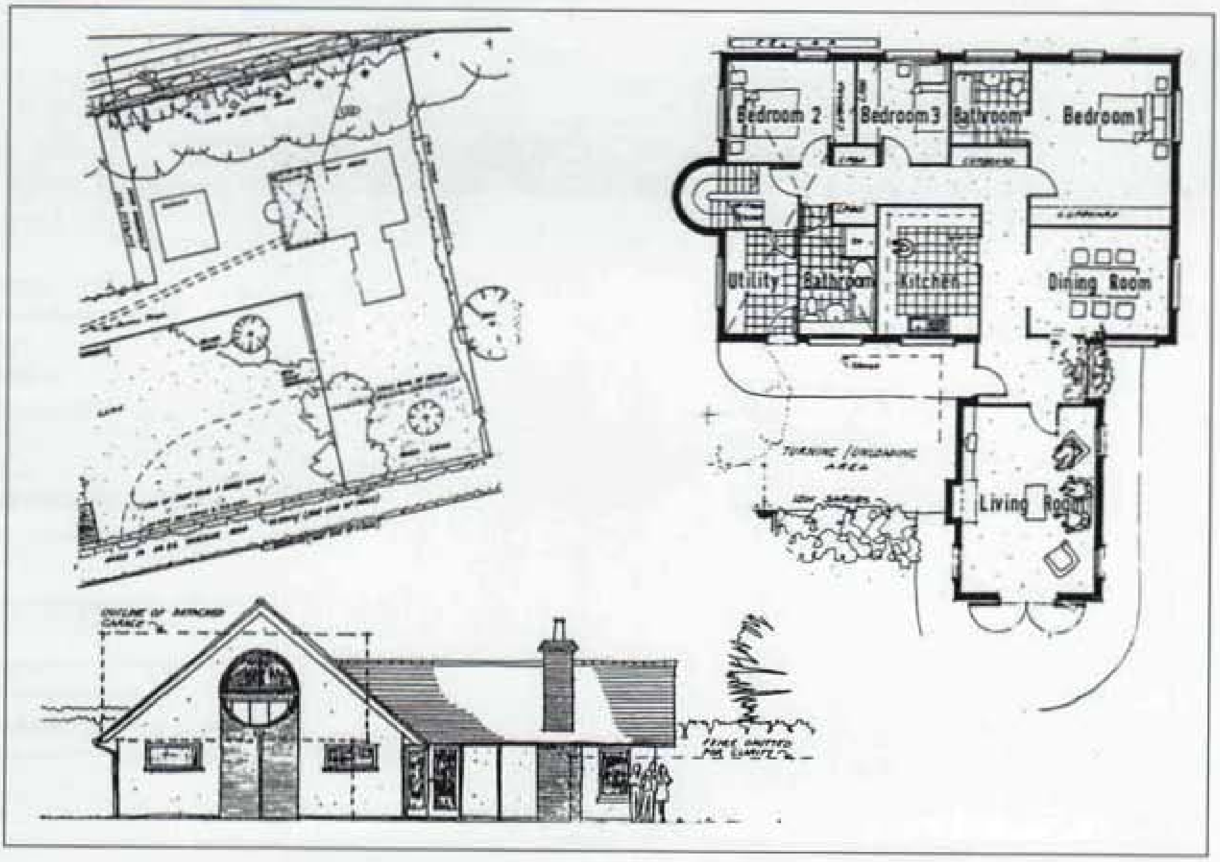
Air leakage: Target < 3 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery.

Heating system: Gas-fired condensing boiler, mains-pressure hot water storage tank and underfloor heating.

Energy use: Not known.

Costs: About £600/m².



IN-SITU CONCRETE

The Energy Showcase, Lyonshall, Herefordshire (1990-95)

Client and energy consultant: David Olivier, Energy Advisory Associates.

Architect: Derek Taylor, Altechnica, Milton Keynes.

Structural engineer: Chris Mattingly, Hereford.

Mechanical services design by Fulcrum Engineering Partnership.

Assistance with thermal simulations by Chris Martin, Energy Monitoring Co. Ltd.

100 m² cottage. Flat rural site; no mains services except electricity. The first UK house planned to reach zero net CO_2. Greenhouse for food production, in advanced glazing, extends across one-half of the south facade.

Floor: Modified suspended concrete, with 200 mm insulation, (U-value = 0.14 W/m²K).

Walls: In-situ concrete, 300 mm insulation within supporting structure of local timber, air barrier, cavity, external render (U-value = 0.10 W/m²K).

Roof: 400 mm cellulose fibre (U-value = 0.08 W/m²K). North slate-clad; south glazed.

Windows: Windows with suitable thermal and optical properties being developed, in discussion with North American and Scandinavian authorities (U-value = 0.7 W/m²K).

Air leakage: Design 0.2 ac/h at 50 Pa. Similar to recent Swiss and German 'zero-energy' houses.

Space heating: Total energy costs zero. No woodstove or other backup.

Water heating: Solar with LPG backup.

Ventilation: Mechanical ventilation and heat recovery; designed for low electricity use and high heat recovery.

Water: Borehole for water supply, shared with nearby house.

Cooking: LPG. Use justified by whole-system arguments. Decision made not to impose large peaks on the grid by use of electric cooking.

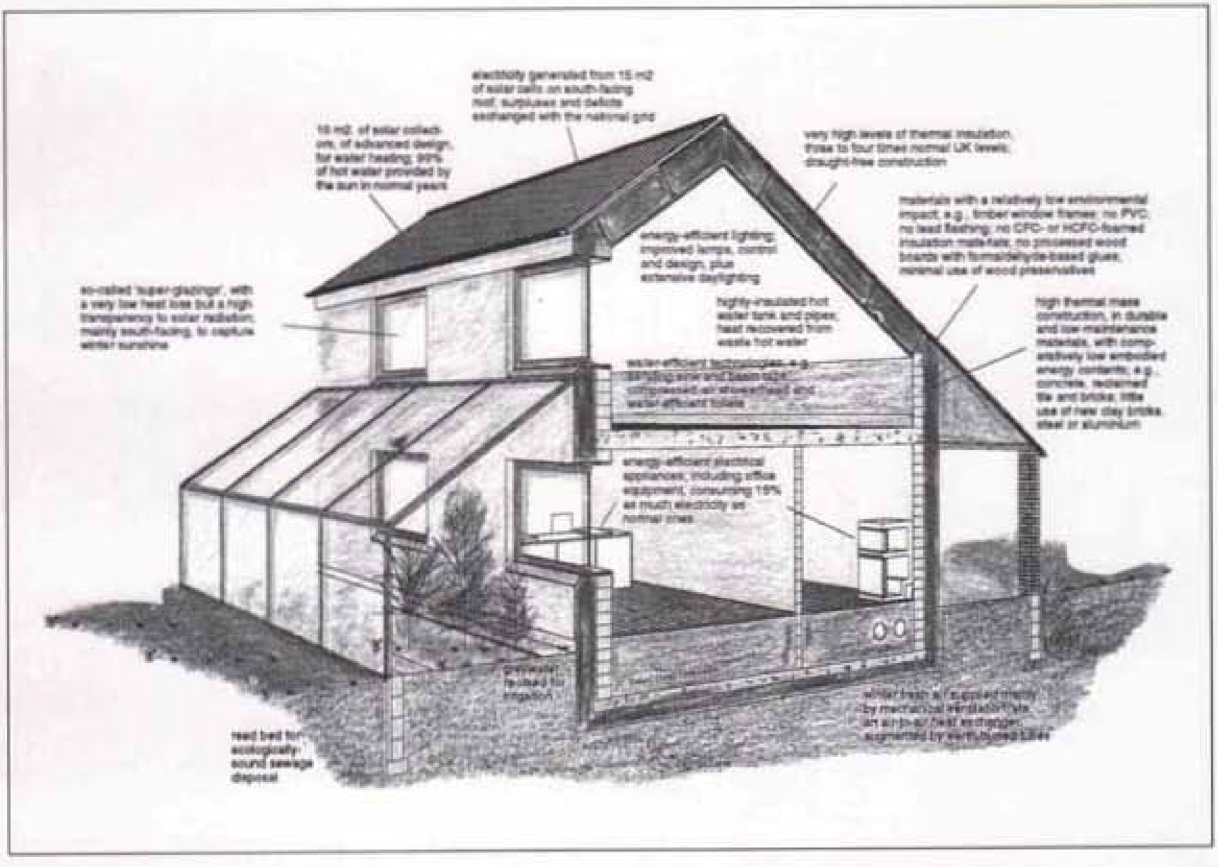
Electricity supply: Grid-connected PV system. Necessary area to be minimised by only using electricity for essential purposes.

Lighting and electrical equipment: 'World class' energy efficiency; to be imported as necessary.

Environmentally beneficial measures: Designed for long, low-maintenance life. Avoidance of materials with a high environmental impact. Choice of structural materials for low embodied energy.

Energy use: Net fossil fuel use zero. Limited tree planting on site to offset use of LPG for cooking. Small net electricity surplus from the grid-connected PV system.

Costs: Not known.



TIMBER FRAME FACTORY-BUILT

L E C S Housing, Saxmundham, East Suffolk (1983)

Designers: Clive Latimer and Nick Baker, Cambridge.

Low Energy Component System (LECS). 88 m^2 one-storey house on remote site in East Anglia,. Designed to be mass-produced from modular components; built entirely of lightweight materials and finishes. Similar buildings designed for factory production, after experience with the prototype.

Probably the first highly insulated timber frame house in the UK. Stressed-skin construction; ie the building is a composite structure, which gains strength from the insulation material, not the timber components alone.

Floor: Concrete. No insulation below slab. The dense concrete block foundation walls are insulated externally with a strip of 100 mm polyurethane foam, to a depth of 1 m.

Walls: 250 mm glass fibre within lightweight units in a stressed-skin construction, faced with oil-tempered hardboard, cedar-clad (U-value = 0.14 W/m^2K).

Roof: Pitched, with two east-west valleys at 2.4 m centres. Insulated with 300 mm glass fibre and aluminium-clad externally (U-value = 0.12 W/m^2K).

Windows: (1) Low level - double glazed, with internal insulating shutters of 50 mm polyurethane foam designed to be used in cold weather (U-value = 2.9/0.5 W/m^2K with shutters open/closed); (2) High level on west gable ends, out of human reach - 2+2-glazed (U-value = 1.5 W/m^2K).

Air leakage: Not known. Much attention was given to creating an airtight structure.

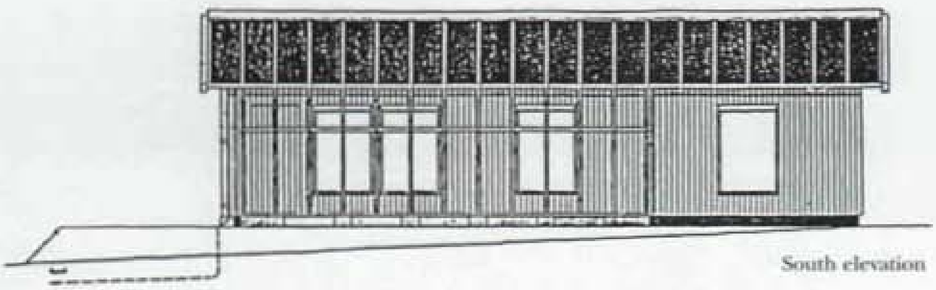
Ventilation: Natural ventilation, using adjustable low level inlets; air enters influenced by wind and stack effect, and exits at the ridge.

Space and water heating: Double glazed conservatory on south wall preheats air which passes through 25 m^2 solar air collectors on the roof. The resulting warm air heats the house directly or is stored in a 1.5 m^3 insulated water tank below the house, using an electric heat pump. Space heat distribution is by a perimeter fan coil system; it needs water at a minimum supply temperature of 55°C.

Backup space heat comes from a small solid fuel stove and water heat from an LPG-fired instantaneous heater.

Energy use: In its first winter, needed little space heating energy input from February to April. Estimated peak space heat demand 1.5 kW.

Costs: Not known.



South elevation

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TIMBER FRAME FACTORY-BUILT

Two Mile Ash, Milton Keynes (1985)

Architects: Feilden Clegg Design, Bath, with Research in Buildings Group, University of Westminster.

The first group of superinsulated houses in the UK to be intensively monitored. Four superinsulated houses were compared with four control houses, which met the Building Regulations of the time.

Floor: Ground-bearing concrete with 100 mm extruded polystyrene under the slab (U-value = 0.2 W/m²K).

Walls: Factory-assembled timber frame. Plasterboard, 40 mm cross-battens with glass fibre forming a protected services cavity, vapour barrier, 145 mm studs filled with glass fibre, render or brick cladding (U-value = 0.18 W/m²K).

Roof: 300 mm glass fibre over and above joists, with services zone below plasterboard (U-value = 0.12 W/m²K).

Windows: 3-glazed, with argon and one sputtered low-emissivity coating (U-value = 1.5 W/m²K).

Much attention was given to creating an airtight structure. The factory assembly left few joints to be made on site. These joints were sealed with in-situ polyurethane foam. Services entries were carefully designed and sealed.

Air leakage: 1.47 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery system.

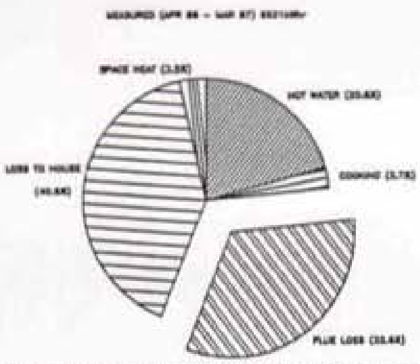
Space heating: A gas boiler serving a coil in the ventilation ducts, via a Gledhill Cormorant thermal store.

A very good standard of comfort. Mechanical ventilation and heat recovery worked well with monitored efficiencies of 75-80%, completely eradicating condensation. The project was let down by the heating system which had an overall efficiency of 28.2%.

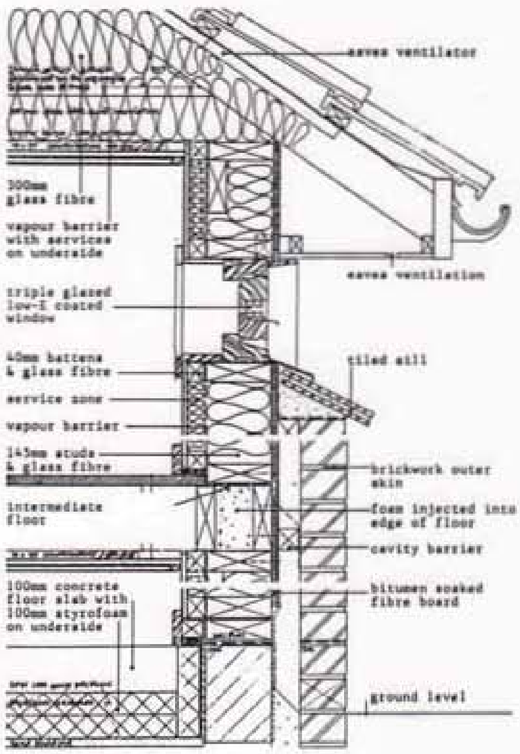
Energy use: Measured 1985-86:

Energy carrier	Purpose	Usage kWh/m²/yr
Gas	Space/water heating	123
Gas	Cooking	3
Electricity	Ventilation, lighting and appliances	39
TOTAL		**165**

Costs: An overcost of £2193 at 1985 prices, comprising 6% of the sale price. It was estimated that the savings in running costs would offset the additional mortgage repayments, and in later years outweigh them.



Superinsulated houses mean gas usage, measured from April 1986 to March 1987.



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TIMBER FRAME SITE-BUILT

Lifestyle 2000, Energy Park, Milton Keynes (1986)

Designer: Timber Research and Development Association (TRADA).

A timber frame house based on the Canadian R-2000 performance standard. Built for the Energyworld exhibition. Combines high insulation and airtightness with passive solar features.

Floor: (1) 75 mm extruded polystyrene under 100 mm concrete (U-value = 0.23 W/m²K); (2) 160 mm mineral fibre between joists in suspended timber floor (U-value = 0.18 W/m²K).

Walls: 13 mm plasterboard, 25 mm services cavity protecting vapour barrier, 90 mm mineral fibre between 38 x 89 mm studs, plywood sheathing, 50 mm extruded polystyrene, cavity, facing brick (U-value = 0.25 W/m²K).

Roof: Pitched roof with 200 mm rock fibre (U-value = 0.19 W/m²K).

Windows: Low-emissivity double glazing in timber frames (U-value = 2.1 W/m²K).

Air leakage: 1.7 ac/h at 50 Pa.

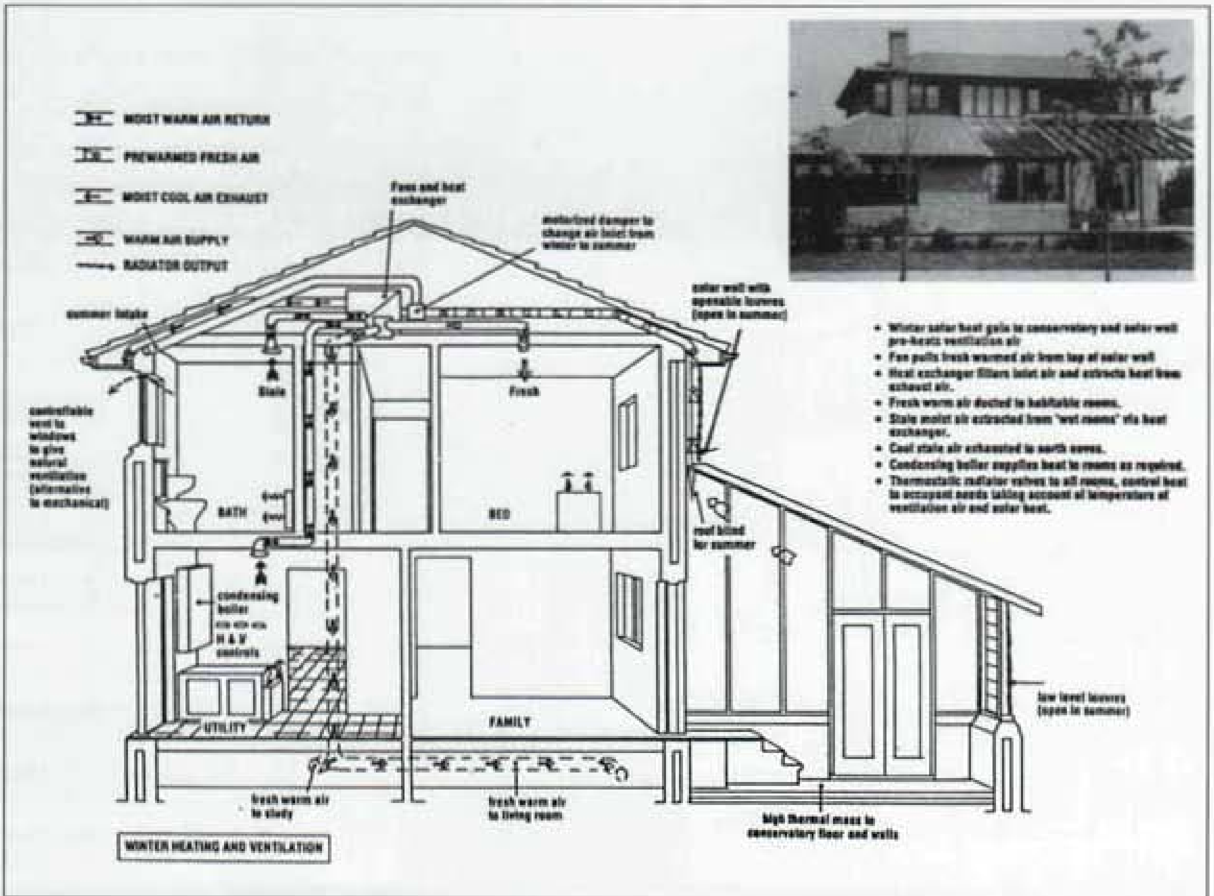
Much attention was given to reducing air infiltration, particularly with the services distribution: wiring and plumbing were distributed in the services void in the wall. Main sealing problems were on masonry chimney breast.

Ventilation: Conservatory and glazed 'solar wall' used for winter preheat of supply air for mechanical ventilation and heat recovery.

Space heating: Gas condensing boiler serving radiators with TRVs.

Energy use: Not known.

Costs: Not known.



TIMBER FRAME SITE-BUILT

TTL Concept House, Futureworld, Milton Keynes (1994)

Designer: TRADA Technology Ltd.

A prototype house using prefabricated I-beams in factory-produced panels to produce a flexible, highly insulated house. The I-beams are used in wall, floor and roof panels to provide long spans, as necessary to eliminate internal load-bearing walls. They are structural composites consisting of laminated veneer timber flanges and plywood webs.

Floor: Suspended floor panels delivered complete with plywood deck, 300 mm insulation and impregnated softboard layer on underside (U-value = 0.11 W/m²K).

Walls: 240 mm mineral fibre between I-beams on 600 mm centres. Externally clad by render or vertical boarding on impregnated softwood. Internally clad by cellulose-reinforced plasterboard with two coats of sealer, acting as a vapour control layer (U-value = 0.15 W/m²K).

Roof: The roof insulation follows the slope.

300 mm mineral fibre between deep I-beams. Faced with plywood internally, and a breather membrane and 50 mm air space above the insulation (U-value = 0.12 W/m²K).

Windows: Double glazing with 20 mm air gap, wood frames (U-value = 2.7 W/m²K).

Air leakage: Not known.

Ventilation: Passive stack ventilation with humidity-controlled exhaust and supply air grilles.

Space heating: Gas-fired 'energy saving' boiler serving radiators with TRVs, all on internal walls.

Energy use: Not known.

Costs: Not known.


Ground floor


First floor

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TIMBER FRAME SITE-BUILT

Self-Build House, St Harmon, Radnorshire, Wales (1994)

Architect: Patrick Borer, Pen-y-Bont-Fawr, Powys.

Modified 'Segal Method' timber frame post-and-beam house in rural area. 1.5-storey house, 91 m² on ground floor but with additional space in loft.

The south elevation is mostly covered by a single glazed sunspace. Much of north wall is covered by porch/store. Roof lights provide good daylight and summertime ventilation. Cellulose fibre insulation with taped vapour control layer is expected to give good wind tightness. Spaced studs and rafters and counter-joists ensure there is minimal thermal bridging, as well as being economical with timber.

Floor: Suspended timber with 210 mm cellulose fibre. Counter joists to reduce thermal bridging and provide services zone (U-value = 0.21 W/m²K).

Walls: Plasterboard finish 19 mm wiring void, Kraft paper vapour barrier, 50 x 50 mm studs, 50 mm gap interrupted only by plywood spacers, 150 mm cellulose fibre, external render on woodwool slabs on bitumen-impregnated fibreboard (bif) sheathing (U-value = 0.25 W/m²K).

Roof: Plasterboard, 19 mm services void, Kraft paper vapour barrier, double rafters, with 50 x 50 mm below, and 150 x 50 mm above, all filled with 300 mm cellulose fibre, bif sheathing, counter-battens and concrete tiles (U-value = 0.13 W/m²K).

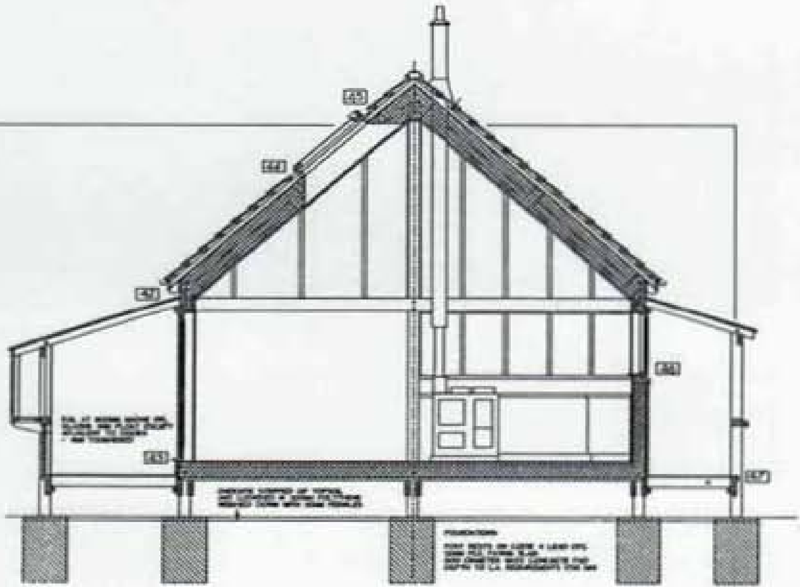
Windows: Mixture of double and triple glazing in timber windows and doors (U-value = 2.1/3.0 W/m²K).

Space and water heating and cooking: Provided by Rayburn, burning wood on a renewable basis. The Rayburn also provides some winter-time ventilation, together with extract fans.

Environmentally beneficial measures: All timber (structural, carcassing, joinery, windows and doors) is locally-sourced larch, converted and air-dried locally. No timber preservatives are used.

Energy use: The first year's use equates to about 200 kWh/m²yr for heating and cooking. It appears that the cooker is inefficient and causes much overheating.

Costs: Approximately £35 000 at about £250/m². This excludes the value of the owners' own labour.



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TIMBER FRAME SITE-BUILT

Self-Build Houses at Walter Street, Bristol (1995)

Client: Bristol Churches Housing Association.

Architect: Patrick Borer, Pen-y-Bont-Fawr, Powys.

Modified 'Segal Method' self-build timber post-and-beam frame houses for housing association.

68 m² single-storey houses (with additional space in warm loft). L-shaped courtyard plans combine privacy with good solar access and shelter. Front doors lobbied. Cellulose fibre insulation with taped vcl gives good wind tightness. Spaced studs and I-beam rafters and counter joists ensure there is minimal thermal bridging as well as being economical with timber.

Floor: Suspended timber with 230 mm cellulose fibre (U-value = 0.15 W/m²K).

Wall: Timber frame with spaced 50 x 50 studs - using plywood spacers, 150 mm cellulose fibre insulation. External fibre-reinforced cement (FRC) sheeting or timber cladding on bitumen-impregnated fibreboard (bif) sheathing. Internally Kraft paper vapour control layer and plasterboard finish (U-value = 0.21 W/m²K).

Roof: Timber 'Masonite' rafters filled with 300 mm cellulose fibre in warm roof section. Trussed rafters with 300 cellulose fibre elsewhere. Bif sheathing counter battens and concrete tiles above. Kraft paper vapour control layer and plasterboard finish below. (U-value = 0.11 W/m²K).

Windows: Double glazed, air-filled, one low-emissivity coating, in timber windows and doors (U-value = 2.1 W/m²K).

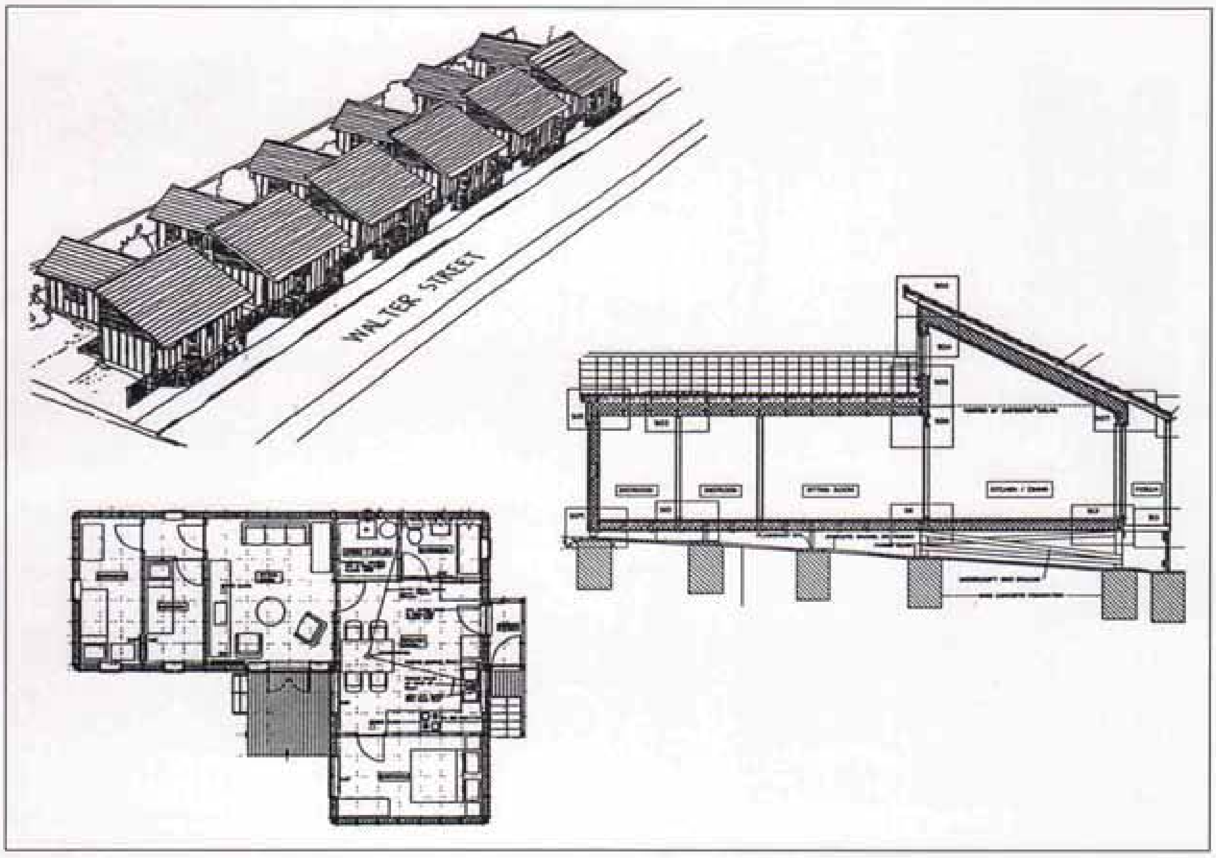
Space and water heating: Condensing gas-fired boiler with heat store. Dataterm energy manager.

Ventilation: Extract fans in 'wet rooms', plus trickle vents.

Environmentally beneficial measures: All timber (structural, carcassing, joinery, windows and doors) is home-grown larch, converted. There are no wood preservatives.

Energy use: Not known.

Costs: These levels of insulation are affordable with Housing Corporation financing by the 'self-build for rent' model. The tenants get low rent and a cash premium for their labours.



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TIMBER FRAME SITE-BUILT

Low Energy House, Great Oxendon, Market Harborough, Leicestershire (1984)

Designed, built and occupied by Chris Dawson.

One of two houses built to develop a patented timber space frame which incorporates 300 mm of insulation in the walls. Probably the most highly insulated timber frame house in the UK.

Floor: Solid concrete with 50 mm expanded polystyrene under 18 mm tongued and grooved chipboard (U-value = 0.4 W/m²K).

Walls: Plasterboard on 300 mm wide timber space frame insulated with glass fibre, plywood diaphragms, cavity and artificial stone outer leaf. A taped and lapped polyethylene vapour control layer on the warm side of the insulation is taken behind the electric boxes and fully sealed at services entries. The space frame consists of ladder framing using small section timbers and stiffened using plywood diaphragms (U-value = 0.11 W/m²K).

Roof: Pitched roof is insulated with 300 mm of glass fibre insulation at ceiling level (U-value = 0.12 W/m²K).

Glazing: Double glazed low-emissivity glazing with 12 mm air gap in timber frame. The space frame allows insulated shutters to be incorporated in the deep reveals (U-value = 2.5 and 0.38 W/m²K with shutters closed).

Heating: The house was built with a solid fuel central heating system but this has never been used. Heating is only required during the coldest two months of the year when an electric radiator is used to heat the house during the off-peak tariff using cheap-rate electricity. The owner reports that usually this is all that is required except in the living room on very cold dull afternoons when a top-up is used before the shutters are closed. The owner is clear that the extra costs of the timber frame and insulation can be offset by the use of very cheap heating systems.

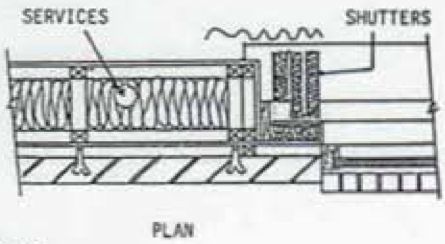
Ventilation is natural using opening windows. There have been no condensation problems.

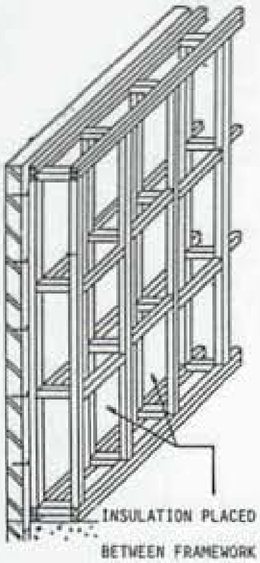
A secondary advantage of the timber space frame is that it is structurally stable with no cross-grain shrinkage, which is sometimes a problem with timber frame construction. Indeed, solid masonry internal walls have been used to provide some thermal mass with no problems of cracks at the joints with the timber frame.

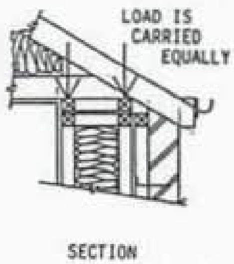
Energy use: Not known.

Costs: Not known.

Patent No GB 2188078







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TIMBER FRAME SITE-BUILT

Potters Bar Eco-House (1995)

Architect: Architype Ltd, London.

A demonstration ecological house initiated by LAWN (Living and Working Naturally). The building will be autonomous in terms of water and electricity. Rainwater will be collected and stored to provide the entire water needs of the occupants. Grey water will be recycled and reused. The toilet will be composting. There will be no connection to the electricity grid. A domestic combined heat and power (CHP) unit is being developed to supply all electricity needs and heating and hot water.

Conservatory incorporated in corner of L-shaped plan provides solar gains from the south-east and south-west.

Floor: Suspended timber 300 mm deep insulated with cellulose fibre (U-value = 0.11 W/m²K).

Walls: Double stud timber frame incorporating 300 mm of cellulose. Lined internally with plasterboard and externally with bitumen-impregnated soft board and clad in home-grown Douglas fir (U-value = 0.10 W/m²K).

Roof: Flat roof using a waterproof membrane on top of 300 mm deep timber I-beams incorporating 300 mm of cellulose insulation. Finished with plasterboard internally (U-value = 0.11 W/m²K).

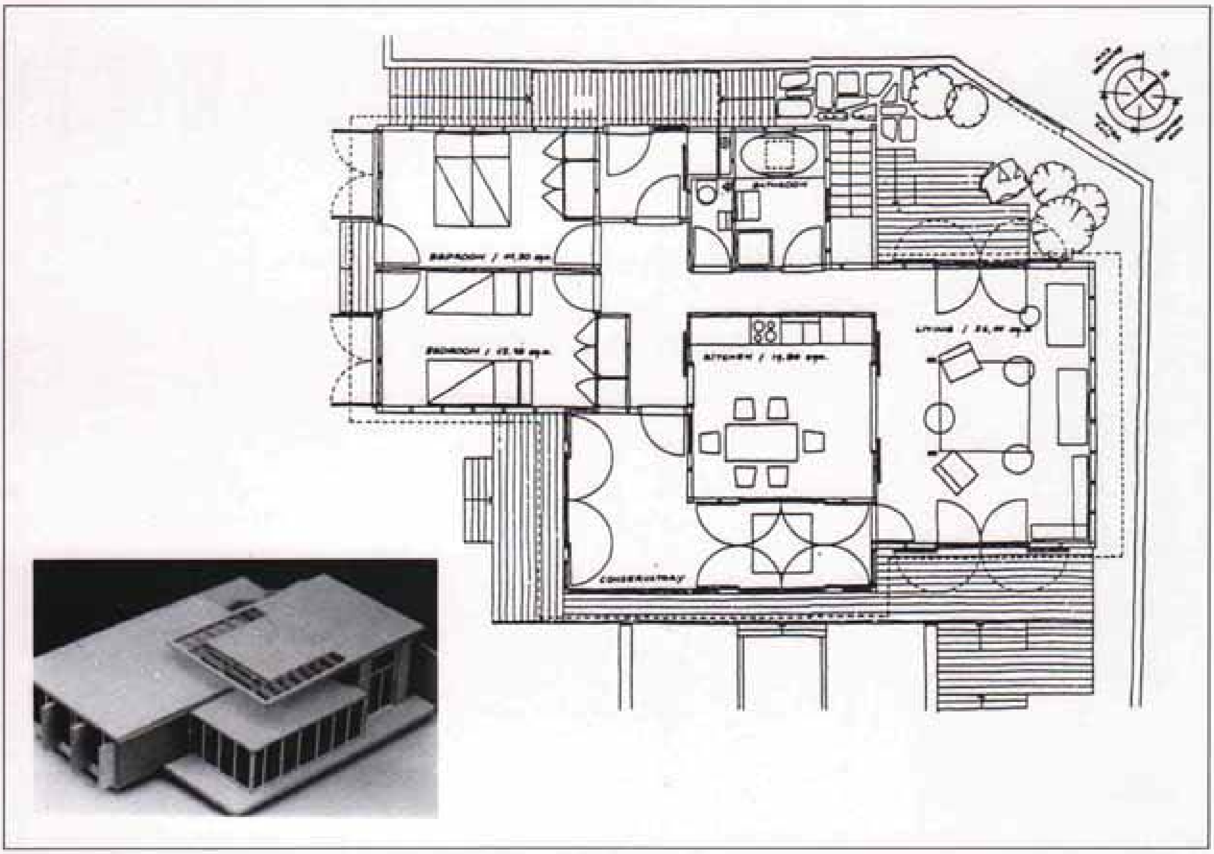
Windows: Double glazed timber windows with low-emissivity coating and argon filling (U-value = 1.5 W/m²K).

Heating and hot water: Domestic scale CHP unit heats hot water and underfloor heating. Excess hot water will be stored in large interseasonal water tanks.

Electricity will be provided from the CHP unit. All appliances will be of 'ultra-low' energy consumption and managed to minimise use.

Energy use: Not known.

Costs: £400/m².



TIMBER FRAME SITE-BUILT

Birchdene Drive Self-Build (1994)

Client: Greenwich Self-build Co-op and South London Family Housing Association

Architect: Archetype Ltd, London.

The third self-build scheme constructed by Greenwich Self-Build Co-op and funded by South London Family Housing Association using the self-build for rent model. This phase of 12 houses is currently under construction, with the second phase of houses planned for 1995. The scheme is forming the focus for the development of Thamesmead Sustainable Village Development, which will integrate low-energy housing with training and employment and wider issues of sustainability and autonomy.

A new and innovative energy efficient self-build system has been developed in conjunction with Swedish timber company, Masonite AB. Masonite is a composite timber beam which is stronger, lighter and easier to handle than solid timber. It is also more 'ecological', both in its manufacture, requiring smaller trees and utilising waste from machining, and in its performance, with greater continuity and thickness of insulation.

Floor: Concrete slab with 75 mm of cellulose insulation between battens, chipboard (U-value = 0.39 W/m²K).

Walls: Plasterboard on timber frame using 170 mm I-studs filled with cellulose, lined externally with bitumen-impregnated soft board and clad in home-grown Douglas fir (U-value = 0.25 W/m²K).

Roof: Pitched roof using 350 mm deep timber I-beams (50 x 50 mm softwood flanges and 5 mm hardboard webs), insulated with cellulose. Timber deck covered with waterproof membrane and finished with living grass and wild flower roof (U-value = 0.095 W/m²K).

Windows: Double glazed with low-emissivity coating in timber frames (U-value = 2.1 W/m²K).

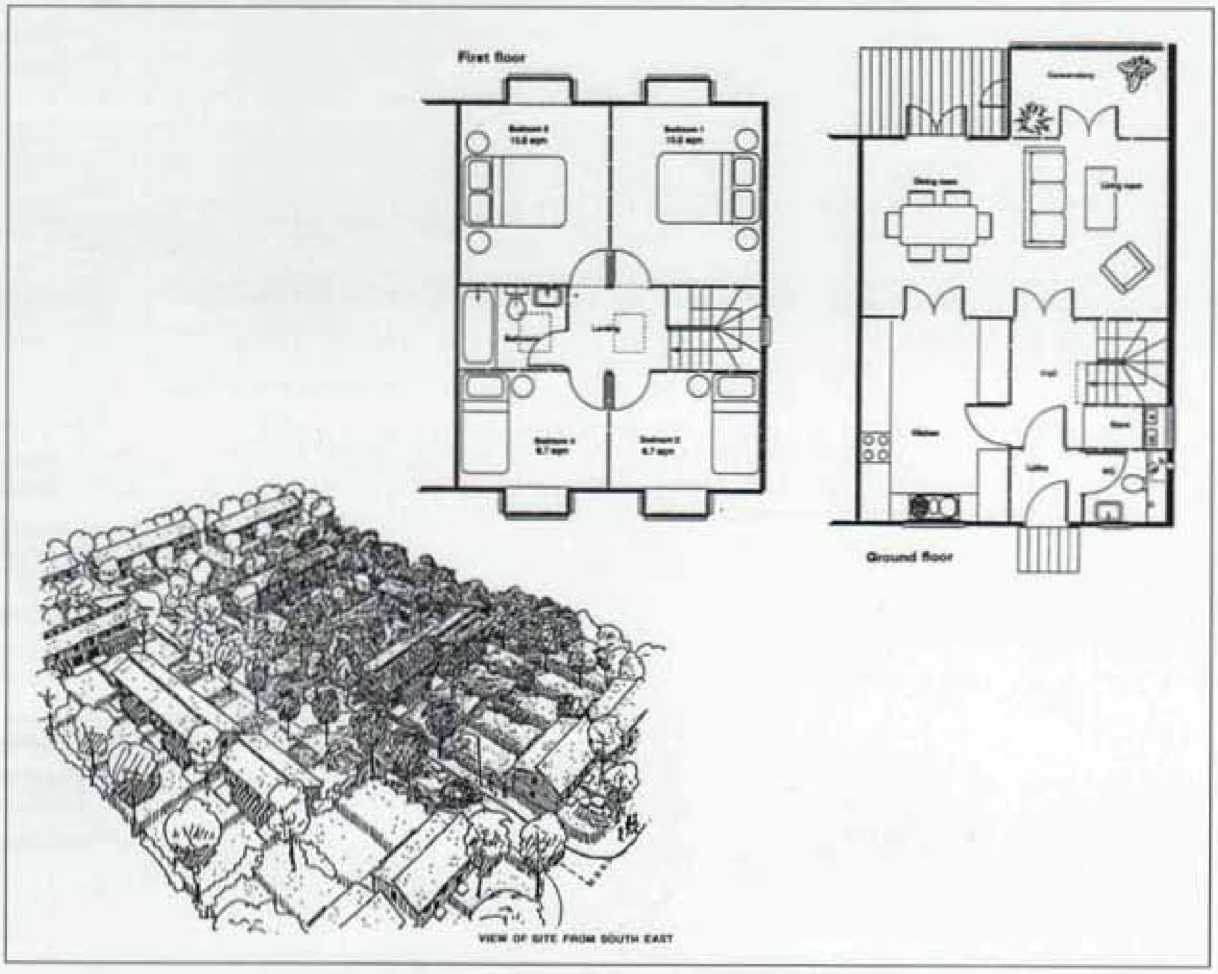
Heating: Condensing boiler and Dataterm boiler energy manager and thermal store.

Water: Rainwater is collected from the roof to flush WCs. It is intended that grey water will also be collected and treated for reuse.

Environmentally beneficial measures: Uses home-grown timber external cladding, organic non-toxic stains and paints and natural floor finishes. The grass roof is seen as making a positive contribution to the local environment by absorbing CO_2 and heavy metals, providing a wild life habitat and a pleasant outlook.

Energy use: Not known.

Costs: £370/m².



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TIMBER FRAME SITE-BUILT

Crickhowell Tele-Village, Powys, Wales (1994-95)

Client and developer: Acorn Tele-villages Ltd, Hereford.

Architect: Powys County Architects Department, Llandrindod Wells.

Limited contribution to the thermal design by Energy Advisory Associates.

Land at Upper House Farm, Crickhowell, Phase one 17 units, 55 m² upwards. Phase two 20 units. In the Brecon Beacons National Park. Subject to detailed aesthetic control.

May be the first UK housing project to apply similar levels of energy efficiency, in a large group of UK-built timber frame houses, to those which Two Mile Ash demonstrated in imported Finnish construction.

Floors: Suspended timber with 200 mm cellulose fibre, over a ventilated crawl space (U-value = 0.2 W/m²K). Some houses will have insulated concrete basements.

Walls: Timber frame with total of 200 mm mineral fibre. Mix of rendered and stone-clad (U-value = 0.20 W/m²K).

Roof: 250 mm mineral fibre between and above rafters (U-value = 0.17 W/m²K).

Windows: Made of UK native timber. Double glazed with argon and one 'pyrolytic' low-emissivity coating (U-value = 2.1 W/m²K).

Care to reduce air leakage and thermal bridging by timber.

Air leakage: Manufacturer to achieve < 2 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery.

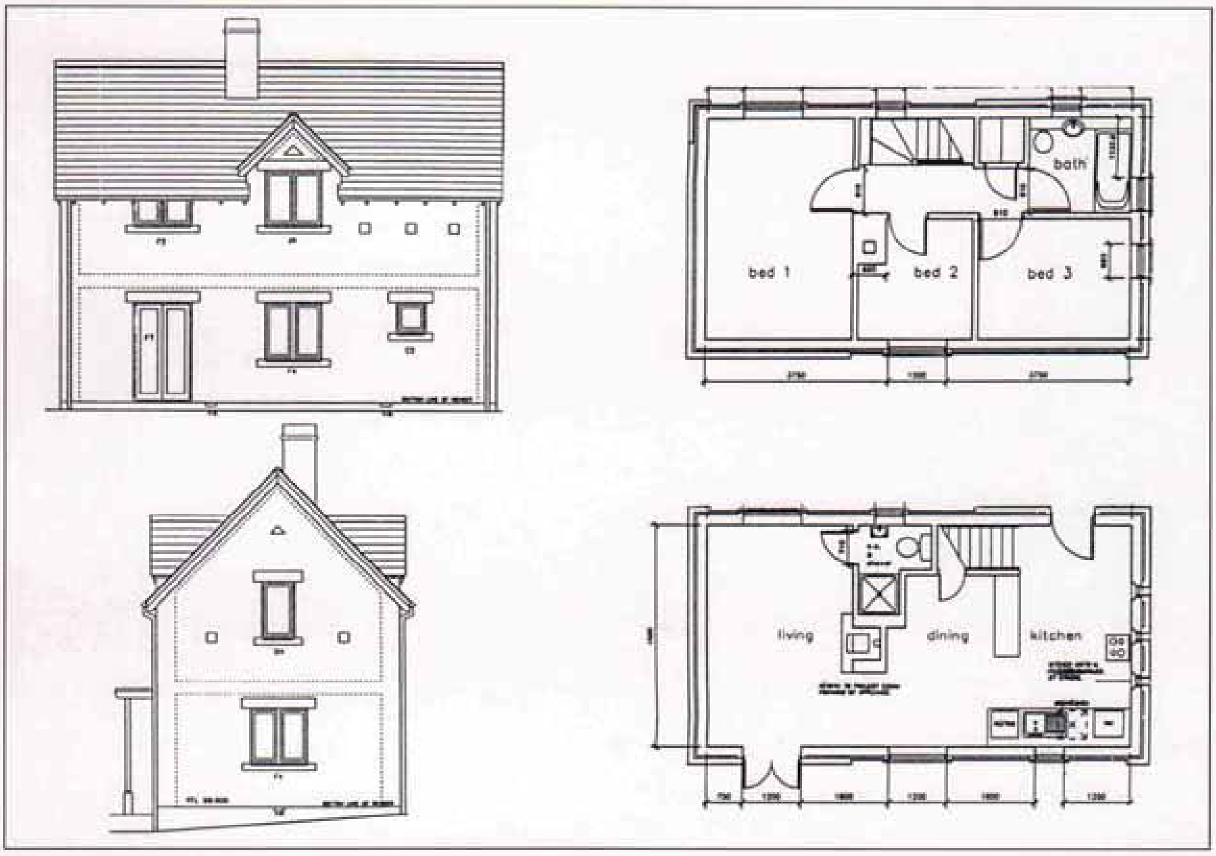
Heating: Gas-fired combi. boilers and warm air heating integrated with ventilation. Woodstoves in larger houses.

Lighting: Energy efficient fluorescent.

Electrical equipment: Was to have energy efficient models of all the major electrical appliances; now likely to be sold without electrical appliances.

Energy use: Calculated space heating energy about 30 kWh/m²yr. Total energy use estimated to be 70-100 kWh/m²yr.

Costs: Not yet known.



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TIMBER FRAME SITE-BUILT

Four-Bed Detached House, Futureworld, Milton Keynes (1994)

Builder: Admiral Homes Ltd for the Electricity Association.

Architect: The Charter Partnership, Bedford.

A highly insulated 234 m² luxury spec house built for the Futureworld Exhibition in Milton Keynes. Uses proprietary steel and plasterboard dry lining system to create services zone and support 150 mm insulation on inside of a 100 mm insulated timber frame.

Floor: Suspended timber with 150 mm of glass fibre (U-value = 0.20 W/m²K).

Walls: Plasterboard on free-standing steel studs, services void, polyethylene vapour control layer, 150 mm glass fibre hung across 100 mm timber frame insulated with glass fibre, plywood sheathing, cavity, brick or block and render cladding. (U-value = 0.15 W/m²K).

Polyethylene carefully sealed around services penetrations using purpose-built tube and disk.

Roof: Pitched roof incorporating 300 mm glass fibre between and over ceiling joists. Special eaves detail ensures insulation is not compressed and connects with wall insulation.

Windows: Double glazed low-emissivity with 14 mm air gap in timber frames (U-value = 2.3 W/m²K).

Air leakage: 2.74 ac/h at 50 Pa.

Heating: Prototype air-to-water heat pump serving Unidaire fan convector heaters with microprocessor control.

Ventilation: Whole house heat recovery ventilation.

Hot water: Two independent unvented off-peak electric storage cylinders.

Lighting: Compact fluorescent lamps are used in most locations.

Energy use: Not known.

Costs: Approximately 20% more than builder's usual spec houses.

TIMBER FRAME SITE-BUILT

'Winslow' Two-Bed Detached House, Futureworld, Milton Keynes (1994)

Builder: Admiral Homes Ltd for the Electricity Association.

Architect: The Charter Partnership, Bedford.

A highly insulated 121 m² spec house built for the Futureworld Exhibition in Milton Keynes. The electric heated house has 'excellent' BREEAM rating. Uses double stud wall incorporating 250 mm of insulation.

Floor: Concrete beam-and-block floor with 100 mm timber joists filled with glass fibre insulation 22 mm chipboard (U-value = 0.3 W/m²K).

Walls: Plasterboard and vapour control layer on double stud wall incorporating 100 + 50 +100 mm of glass fibre, plywood sheathing, cavity, brick cladding (U-value = 0.15 W/m²K).

Roof: Pitched roof incorporating 300 mm glass fibre between and over ceiling joists. Special eaves detail ensures insulation connects with wall insulation.

Windows: Triple glazed argon-filled glazing in composite timber and aluminium frames (U-value = 2.0 W/m²K).

Air leakage: 1.94 ac/h at 50 Pa.

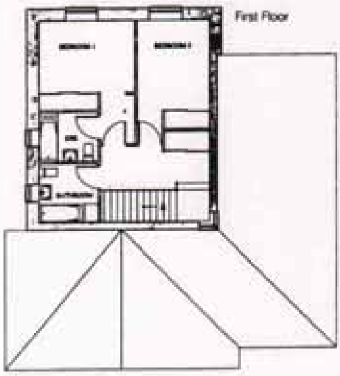
Heating and ventilation: Whole house mechanical ventilation system has electric air-to-air heat pump which supplies heating and ventilation. A top-up system uses thermostatically controlled panel heaters with mains-borne central programming. The programmer allows independent 7-day-a-week programming for each panel heater.

Hot water: Independent unvented off-peak electric storage cylinders.

Lighting: Compact fluorescent lamps are used in most locations.

Energy use: Estimated space heating costs were £61 per year. The SAP rating of the house is 100.

Costs: Approximately 20% more than builder's usual spec houses.



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STEEL-FRAME

Four 1/2-Bed Apartments, Futureworld, Milton Keynes (1994)

Builder: Admiral Homes Ltd for the Electricity Association.

Architect: The Charter Partnership, Bedford.

Four apartments (51 to 66 m^2) contained in a highly insulated steel-frame building. The steel frame allows for clear spans offering flexibility of internal layouts. The apartments have innovative electric heating systems. A large rooflight gives good daylighting to the common entrance and stairs.

Floor: Concrete ground-bearing slab, 75 mm of CFC- and HCFC-free extruded expanded polystyrene and screed (U-value = 0.25 W/m^{2}K).

Walls: Plasterboard fixed to free-standing 48 mm deep steel studs forming a services zone, polyethylene vapour control layer, 150 mm glass fibre covering steel structural studs. The structural steel studs comprise 100 x 65 mm pre-galvanised lipped channels. 100 mm of glass fibre insulation is installed within the frame. On the outside 50 mm dense foil-faced glass fibre batts are fixed to the steelwork with brick tie channels and proprietary mushroom fixings. Brick cladding. Total insulation thickness 250 mm (U-value = 0.15 W/m^{2}K).

Roof: (1) 300 mm of glass fibre between and over the ceiling joists (U-value = 0.12 W/m^{2}K). (2) Over the 'Apsley' apartment at first floor a 'cathedral' roof has 200 mm of glass fibre (U-value = 0.2 W/m^{2}K).

Windows: Double glazed low-emissivity with 14 mm air gap in timber frames (U-value = 2.3 W/m^{2}K). Rooflights over circulation area double glazed (U-value = 3.0 W/m^{2}K).

Air leakage: Target maximum 4 ac/h at 50 Pa.

Heating: The common access areas have electric underfloor heating. The 'Shenley' has an air-to-water heat pump serving underfloor heating coils. The 'Calverton' has electric floor warming and ceiling heating. The 'Apsley' has a prototype hot water thermal storage boiler serving radiators with TRVs on a weather-compensated circuit. The 'Cosgrove' is heated by Celect storage combination heaters with radio teleswitch control for energy optimisation and a mains-borne user control system.

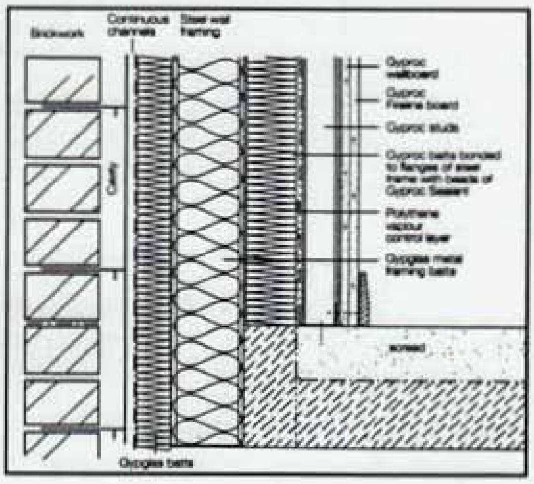
Ventilation: Each apartment has whole unit heat recovery ventilation, serving the whole dwelling.

Hot water: The 'Apsley' has a mains pressure coil in the hot water thermal storage boiler. All others have independent unvented off-peak storage cylinders.

Lighting: Compact fluorescent lamps are used in most locations.

Energy use: Not known.

Costs: Not known.



STEEL-FRAME

Green Street, Festival Park, Victoria Heights, Ebbw Vale, Wales (1991)

Client: British Steel.

Architect: Brown and Parnaby, Abergavenny.

203 m² exhibition house, part of the Garden Festival, since sold. The brief called for dwellings which demonstrated best current practice in low-energy design, and made an environmentally responsible choice of materials.

Floor: Tiles or carpet, screed, concrete raft, 100 mm expanded polystyrene (U-value = 0.25 W/m²K).

Walls: (1) Next to external air - 12 mm plasterboard, well sealed polyethylene vapour barrier, 50 mm polyisocyanurate foam between steel studs, 50 mm foam outside steel frame, cavity, brick or steel cladding (U-value = 0.27 W/m²K); (2) Next to conservatory-plaster, 450 mm dense concrete block, 50 mm mineral fibre, 100 mm dense concrete block, render (U-value = 0.5 W/m²K).

Roof: 300 mm cellulose fibre on attic floor (U-value = 0.12 W/m²K). Softwood rafters, on steel purlins, clad with concrete slates.

First floor: Steel joists with OSB decking.

Windows: Double glazed with 20 mm argon and one sputtered low-emissivity coating on outer pane, in wood frames, of Danish origin (U-value = 2.0 W/m²K). Rooflights similar.

Conservatory: Double glazed in thermally-broken aluminium frames.

Air leakage: Not known. Estimated 5 ac/h at 50 Pa.

Ventilation: Mechanical ventilation and heat recovery, using an exhaust air heat pump.

Space and water heating: Passive solar contribution, with heat stored in the high thermal capacity wall between the conservatory and the house. Heat pump, as above. Direct electric resistance panel heaters as backup; a two-stage thermostat prevents them operating when the output of the heat pump is sufficient. Ventilation air is taken in from the top of the conservatory. Solar water heating with electric backup.

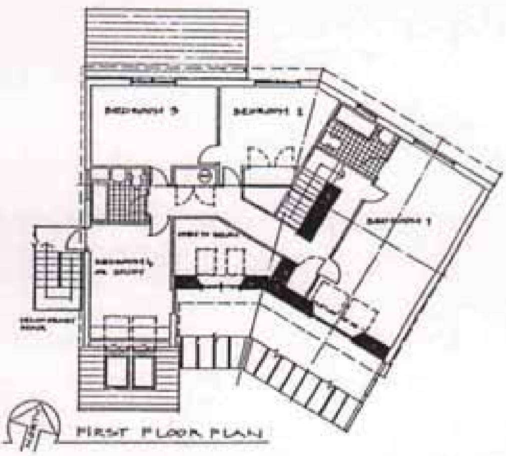
Environmentally beneficial features: Materials chosen for minimum impacts, within the limitations of both the available information sources and the available budget. For example, they used organic paints, the kitchen worktops were marble instead of chipboard, and much of the ground floor was finished with quarry tiles instead of carpets. It was difficult or impossible to locate some materials on the UK market.

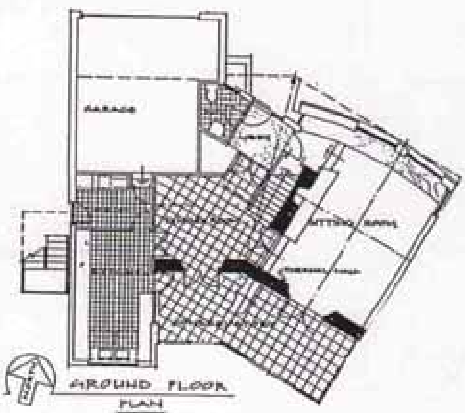
Energy use: See table below.

Costs: Not known.

Estimated energy use

Energy carrier	Purpose	Usage kWh/m²yr
Gas	Space heating including ventilation	47
Electricity	Water heating	17
Electricity	Cooking, lighting and appliances	14
TOTAL		**78**





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EARTH-SHELTERED

The Berm House, Caer Llan Field Studies and Conference Centre, Lydart, Monmouth, Gwent, Wales (1987)

Designer and owner: Peter Carpenter.

363 m² extension to guest house, comprising a staff flat and a row of seven guest bedrooms, all with en-suite bathrooms. Built into a SSW-facing slope, with a 'solar corridor' along the south side.

Floor: Screed, 12.5 mm polyurethane foam, tanking, concrete raft, hardcore (U-value = 0.6 W/m²K).

South walls: 100 mm brick, 100 mm polyurethane foam, 225 mm dense concrete block, tanking, 200 mm stonework (U-value = 0.15 W/m²K).

Retaining wall: 100 mm brick, polyethylene vapour barrier, 100 mm polyurethane foam, 660 mm dense concrete block, tanking, 150 mm (U-value = 0.16 W/m²K).

Roof: 100 mm polyurethane foam, 375 mm concrete, tanking, 2 m earth (U-value = 0.14 W/m²K).

Cross-walls: Fair-faced cavity brick.

Windows: (1) Solar corridor - Air-filled double glazing with one sputtered low-emissivity coating, in aluminium sub-frames, with stone mullions (U-value = 2.6 W/m²K); (2) Between guest rooms and corridor - single glazed.

External doors: Solid timber from hardwood cut on site, with 6 mm low-emissivity double glazing (U-value = 2.5 W/m²K).

Air leakage: Unknown. Probably low. The south walls are tanked and all the windows are fixed and sealed to the tanking.

Ventilation: Continuous, mechanical with supply to corridor and extract from bathrooms. Concentric earth-buried tubes; the incoming air stream recovers a certain amount of heat from the stale air stream.

Hot water: Recirculating loop off oil-fired boiler in main house.

Environmentally beneficial features: Structure designed for long life and low maintenance.

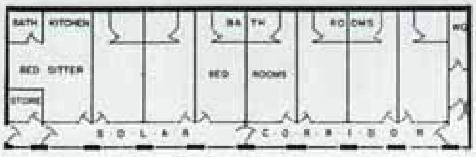
Energy use: Space heating energy zero. Normal annual temperature swing in the guest rooms is from 17.5°C to 24.5°C. This gives rise to few complaints, given that they are used mainly as sleeping rooms and the radiant temperature is the same.

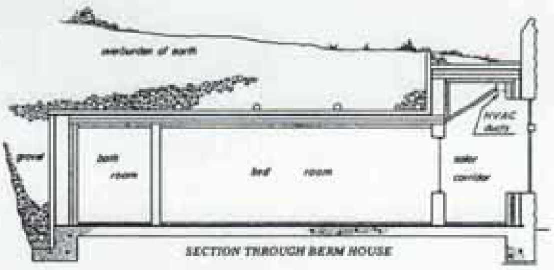
Ventilation electricity use 5 kWh/m²yr.

Total electricity use 14 kWh/m²yr.

Hot water use unmetered.

Costs: Built on a direct labour basis for £330/m².





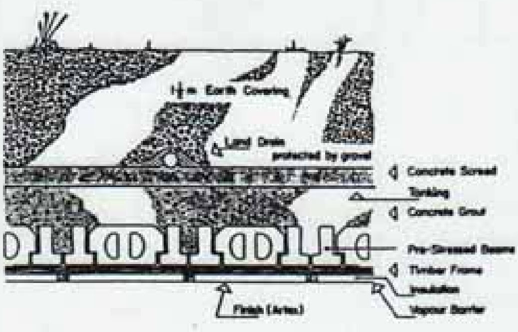


Diagram of section through roof

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EARTH-SHELTERED

Hockerton Houses, Southwell, Nottinghamshire (1994-95)

Architects: Robert and Brenda Vale, Southwell, Nottinghamshire.

Five terraced houses. Single-storey, each 122 m², with a 47 m² conservatory covering the whole of their south facade. On a gentle south slope outside the village.

The local planning authority gave the scheme planning permission in the open countryside, on the grounds that its environmental benefits outweighed the disadvantages. This decision makes post-war UK planning history. The freehold will be owned by a housing co-operative, which will jointly maintain the common areas and will write environmental covenants into the leases for individual houses.

Floor: 300 mm concrete raft upon 300 mm expanded polystyrene.

South walls next to conservatory: 215 mm dense concrete block, 150 mm mineral fibre with plastic ties, 100 mm facing brick.

Retaining wall: 2 x 100 mm dense concrete block as permanent shuttering for 300 mm in-situ reinforced concrete, tanking, 300 mm expanded polystyrene.

Roof: 250 mm concrete beam-and-block, tanking, 300 mm expanded polystyrene, 0.5 m earth and grass.

Windows: 3-glazed with krypton and two sputtered low-emissivity coatings (U-value = 1.15 W/m²K).

Conservatory glazing: Air-filled double glazing with one pyrolytic low-emissivity coating (U-value = 2.3 W/m²K).

Air leakage: No stated target, but the construction should guarantee a fairly low figure.

Space heating: None.

Water heating: Solar.

Ventilation: Mechanical ventilation and heat recovery.

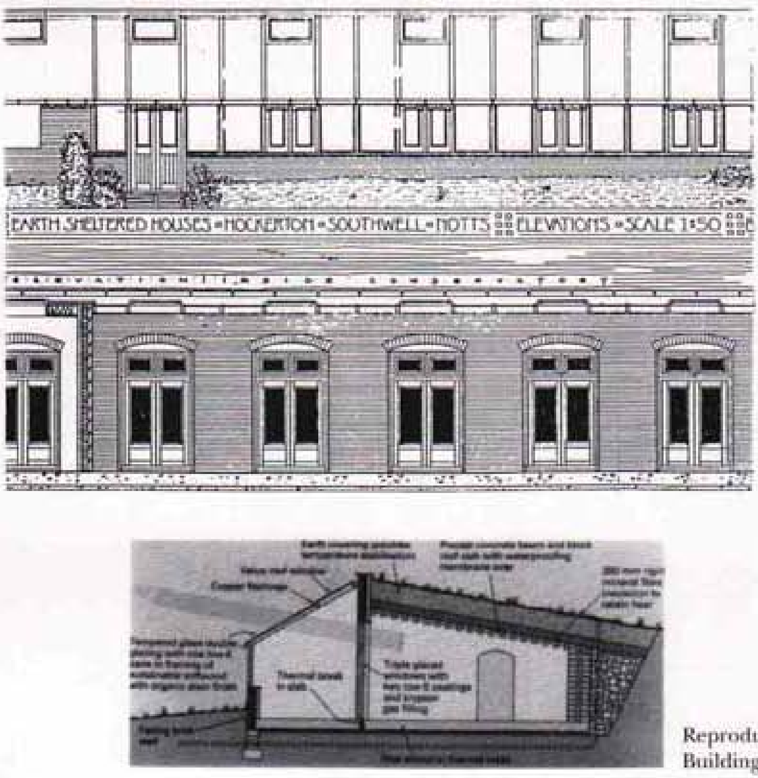
Electrical equipment and lighting: The most energy efficient on the UK market.

Water: Borehole. Reed bed sewage treatment.

Environmentally beneficial measures: Relatively healthy materials throughout; eg polyethylene rather than bituminous tanking, copper gutters, and no chipboard or similar materials.

Energy use: Expected fossil fuel backup is zero, after including the thermal contribution of the solar heating system and the electricity production of the on-site wind generator.

Estimated costs: Including the energy supply systems, £820 per m², excluding the conservatory, or £600 per m² including the conservatory floorspace.



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EARTH-SHELTERED

Kings Cross Eco-House, London (1994-95)

Client: Community Creation, Kings Cross.

Architect: Roy Grimwade Architects, Colchester.

Structural engineer: Ove Arup, London.

Energy consultant: Energy Advisory Associates.

140 m² two-storey house plus lean-to greenhouse. Demonstration project allied to development of housing for the homeless. Will demonstrate possibilities for green housing projects in an inner city setting where the environmental improvements could literally change the landscape from 'grey' to 'green'. Large greenhouse, with advanced glazing, to show feasibility of growing a wider range of plants in the UK winter.

Floor: Concrete raft with 200 mm insulation (U-value = 0.14 W/m²K).

Walls: 200 mm concrete externally insulated with 300 mm cellulose fibre (U-value = 0.12 W/m²K).

Retaining wall: Concrete with 200 mm mineral fibre (U-value = 0.14 W/m²K).

Roof: Concrete with 300 mm insulation, 1 m earth at rear tapering to 0.2 m at front, grass and trees/plants (U-value = 0.11 W/m²K).

First floor: Timber, made partly from trees on site.

Windows: As with Lyonshall and Elmsett, design being developed with higher performance than normally available (U-value = 0.8 W/m²K).

Air leakage: Design value 0.2 ac/h at 50 Pa; ie the same as above-ground Swiss and German zero-energy houses.

Space and water heating: Solar water heating. Passive solar space heating as for Elmsett/Lyonshall; assisted by the earth-sheltered north wall in particular.

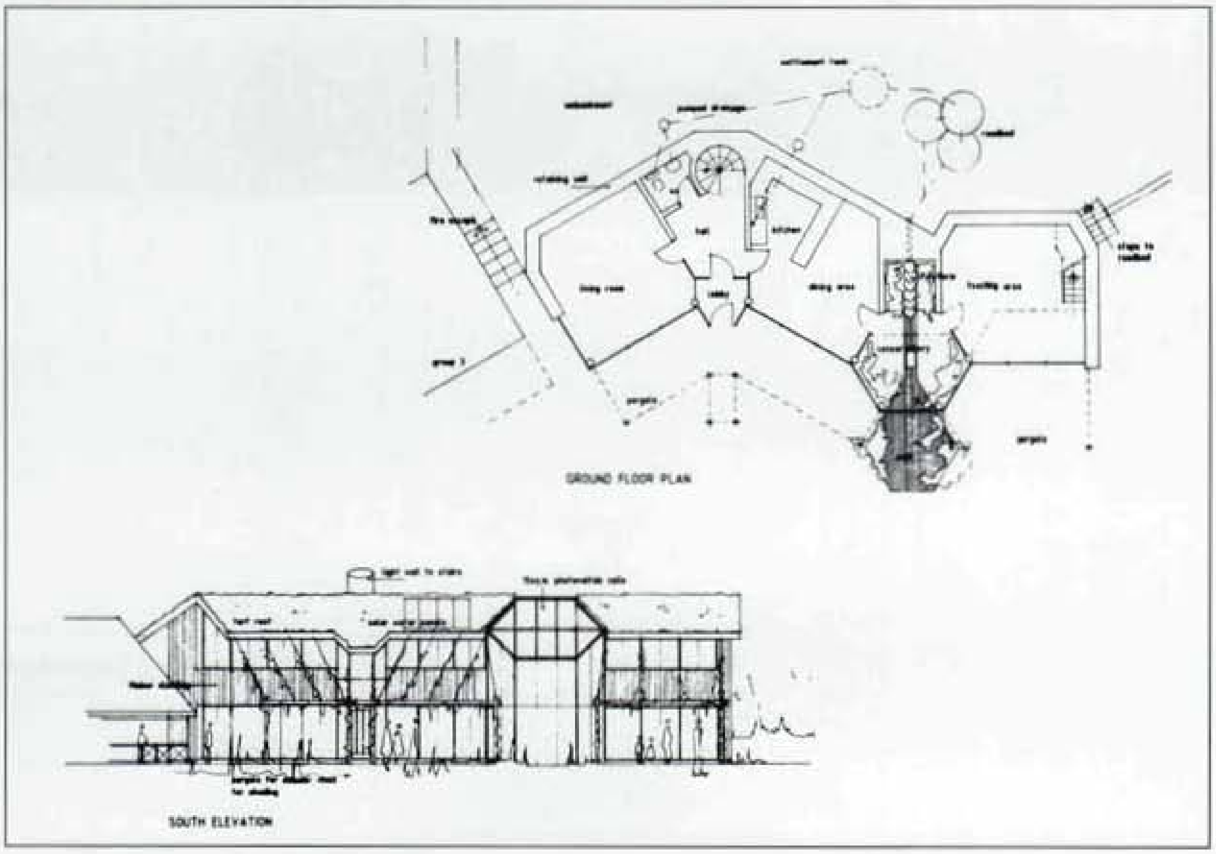
Ventilation: Mechanical ventilation and heat recovery system, of low electricity use.

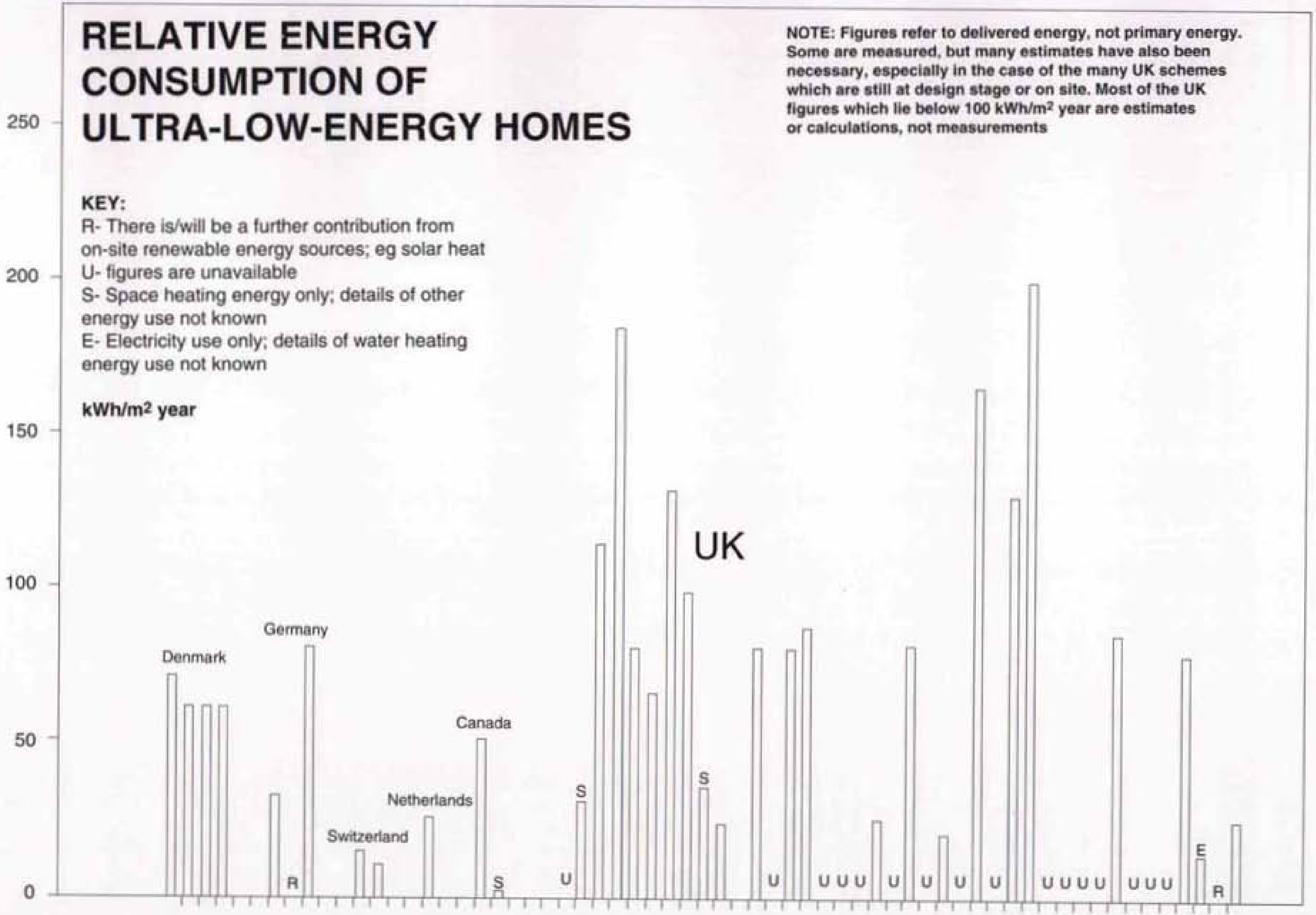
Electricity supply: Grid-connected PV system.

Electrical equipment and lighting: Highly energy efficient; to be 'world class'.

Energy use: Target is 25 kWh/m²yr including active solar. Allowing for surplus from PV system, aim is zero total fossil fuel usage.

Costs: Not yet known.




RELATIVE ENERGY CONSUMPTION OF ULTRA-LOW-ENERGY HOMES
NOTE: Figures refer to delivered energy, not primary energy. Some are measured, but many estimates have also been necessary, especially in the case of the many UK schemes which are still at design stage or on site. Most of the UK figures which lie below 100 kWh/m2 year are estimates or calculations, not measurements
KEY:
R- There is/will be a further contribution from on-site renewable energy sources; eg solar heat
U- figures are unavailable
S- Space heating energy only; details of other energy use not known
E- Electricity use only; details of water heating energy use not known
kWh/m2 year
250
200
150
100
50
0
Denmark
Germany
R
Switzerland
Netherlands
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VARIOUS CONSTRUCTION METHODS

UK

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
1	Low-energy local authority housing	Wakefield, W. Yorks	1980-82	Cavity masonry with high insulation throughout: 75/150/240 mm mineral fibre in floor/walls/roof and double glazed low-e windows	Followed the lead set by the Salford project. Very ambitious by 1980 standards. Fairly low measured floor heat loss
2	Speculative house	Energy World, Milton Keynes, Bucks	1986	In-situ concrete in shuttering: expanded polystyrene permanent timber roof insulated with polyurethane foam panels	Apparently successful. General specification very high
3	Student residences	Glasgow	1990	Cavity brick/concrete block wall with 150 mm insulation; south facade clad with polycarbonate honeycomb	Problems arose with the moveable blinds. The occupants also liked the high internal temperatures experienced in summer and autumn, over 22°C, and wanted the same conditions in midwinter
4	Student residences	Norwich, Norfolk	1991-93	Dense concrete block cavity walls and in-situ concrete floors and roof. Externally rendered. All-electric heating as capacity of gas main limited	Owing to the unfamiliar concept of detailing and building for airtightness, it did not meet the requirements in the specification
5	Student residences	Sunderland	1993	Higher insulation levels than Norwich	Gas heating
6	Social housing	Maldon, Essex	1991	Timber frame	So-called 'breathing' wall construction. Many environmentally-conscious features, but U-values exceed our target and had to be all-electric, not gas heated
7	Social housing	Carshalton, Surrey	1992	Timber frame	Similar to Maldon. Gas heating; however, U-values again exceed our target
8	Custom-built earth-sheltered house.	Bushey Heath, Herts	1993-94	Concrete block and in-situ concrete faced with clay brick	Problems arose with the general quality of construction; unconnected to energy efficiency. Not yet complete.

additional projects 9-19

VARIOUS CONSTRUCTION METHODS

UK

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
9	Self-build retirement bungalow	Bircher, Herefordshire	1994	Cavity masonry with 100 mm polyurethane foam, 50 mm residual cavity	
10	Private housing	Forres, Morayshire, Scotland	1993-	Timber frame of novel design	Insulation levels not exceptional for the climate
11	Single-storey 130 m² house	South Devon	1994-95	Timber frame	'Breathing' wall construction. Wall U-value exceeds our target
12	Self-build 180 m² cottage	Herefordshire	1992-95	Masonry, 1.5-storey, plus partial cellar on remote site; very high insulation and extensive use of reclaimed local stone	Most external works undertaken and other work begins in 1995. Special arrangements designed to minimise initial cost. However, owners desire no publicity
13	Earth-sheltered house	Glen Devon, Scotland	1990	Uses 100 + 150 mm autoclaved aerated concrete cavity block walls with insulated cavity above ground and concrete within cavity below ground. 75 mm roof insulation under min 150 mm soil	Electric heating
14	Buffer houses	Laxay, Isle of Lewis	1994	Timber frame single-storey building with 150 mm insulation walls, 50 mm insulation floor and 200 mm in loft	Interesting use of less well insulated buffer space and humidistat/time switch controlled MHRV unit
15	14 speculative houses	Cornwall	1995	Norwegian timber frame system; 150 mm walls, 300 mm loft, 100 mm floor, condensing boilers	Awaiting planning permission, but 12 of 14 sold already!
16	Diggers self-build	Hollingbury, Brighton	1994	Segal self-build 75 + 50 mm walls, 175 mm grass covered roof, 175 mm floor, condensing gas boilers	
17	12 Autonomous dwellings	Boughton, Notts	1995-6	12 zero CO_2 emission houses based on Vales' autonomous house, see Profile No 10	Local authority has policy to encourage such dwellings
18	Gwalia HA	Swansea	1995?	Low-energy houses (Thermie project)	Could not get information in the time available
19	Marks Tey self-build	Colchester, Essex	1995	150 mm walls, 75 mm floor, 300 mm loft	Self-build for the disabled. Interesting heating system appears to use direct gas-fired low volume storage hot water heater for heating and dhw

additional projects 20-31

VARIOUS CONSTRUCTION METHODS

UK

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
20	10 self-build houses	Drakefell Rd, London SE14	1994-95	Modified Segal 150 mm floor, 150 mm walls, 200 mm loft, condensing combi	
21	48 flats, houses and bungalows	Gateshead	1994	65 mm floor, 100 mm cavity fill, 200 mm loft, d/g low-e	Similar to Saffron Walden (Profile No 15). Grouped heating and MHRV with solar wall preheating supply air. Solar panels. Good tenants manual
22	Sheltered housing	Hull	1994-95	Similar scheme to Gateshead	'Breathing' wall construction. Wall U-value exceeds our target
23	Private house	Frampton Cotterell, Nr Bristol	1994	Masonry with 150 mm cavity insulation, d/g low-e and t/g, 175 mm cellulose loft insulation, PSV	Considerable work to fit tight vapour barrier and seal electrical wiring
24	Social housing	Orkney	1994	Timber frame; 150 mm wall insulation. Notable as very airtight by UK standards – 1.0 ac/h at 50 Pa	Received a brief information package but unable to obtain more technical details in the time available
25	Social housing	Industry Road, Sheffield	1991	Masonry with 150 mm cavity insulation, 250 mm roof, 150 floor, triple glazed low-e argon-filled windows, mech. vent. with heat recovery	Predecessor to Creswell Road (Profile No 7)
26	Private house	Colchester, Essex	1992	Timber frame similar to Maldon (No 6 above)	Total energy use reported at about 80 kWh/m^2
27	Private house	Nr Rotherfield, East Sussex	1993-95	Masonry with 125 mm cavity insulation, low-e argon-filled triple glazing; condensing boiler	
28	Sheltered housing	Peterloo Court, Salford, Lancs	1994	Based on Salford houses (Profile No 2) but to slightly lower standards	
29	Spec houses	Melton Mowbray, Leics	1991	Based on Salford houses (Profile No 2)	
30	Integrated solar dwelling	Brighton	1979	Single-storey 36 m^2 timber frame dwelling. U-values around 0.2 W/m^{2}K	Early experiment in low cost eco living
31	Self-build house	Downpatrick, Northern Ireland	1994	Single-storey timber frame dwelling similar to St Harmon (Profile No 28)	

additional projects 32-34

VARIOUS CONSTRUCTION METHODS

UK

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
32	Tir Gaia	Rhayader, Powys, Wales	1992-	Two-storey timber-/steel-frame house with 200-300 mm mineral fibre and high quality wooden windows. Solar heat stored in water-filled containers in first floor. Will eventually have glazed roof with greenhouse	Completion date unknown. Owner carrying out research on novel insulating shutters. Despite a window U-value of 1.65-2.0 W/m²K, reports down-draughts in severe weather
33	Low-energy housing association development	Clase, Swansea	1993	12 timber frame dwellings with U-values of 0.2-0.25 W/m²K, double glazed low-e windows and small conservatories	By Gwalia Housing Society; see above
34	Rye House Barn	Little Downham, Cambs	1994	Reconstructed farm building with U-values of around 0.2 W/m²K in opaque areas and 2.5 in windows	Numerous environmental features; eg much use of reclaimed materials from other old buildings

ABBREVIATIONS

Low-e low emissivity

dhw domestic hot water

dg double glazing / double glazed

MVHR mechanical ventilation with heat recovery

additional projects 35-45

VARIOUS CONSTRUCTION METHODS

Elsewhere in Europe

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
35	The Minimum Energy Houses	Schiedam, Netherlands	1982-	Precast concrete on pile foundations; 200 mm external insulation. Double glazing with external insulating shutters	Standards nearly as high are now required in the town's social housing, but no longer 'state-of-the-art'. Overcost was 24%
36	Autonomous Solar House	Stavanger, Norway	1989	Concrete block construction, high insulation and airtightness. On south-west coast, in Norway's moderate climate zone	Early example of the genre. Combined solar and wind energy supply. Backup use of wood 35 kWh/m²yr
37	The Haas House/Office	Jona, Switzerland	1984	Concrete raft foundation resting on load-bearing insulation, with concrete turf roof. Active solar system integrated into south glazing	Backup space heating fuel 14 kWh/m²yr. Very low electricity consumption, considering that 20% of the building is used as an office
38	The Solar House	Oberburg, Switzerland	1989	Timber frame	The first 100% solar house in Switzerland
39	The Autonomous Solar House	Castricum, Netherlands	1989	Calcium silicate brick and concrete	Generates all its electricity from PV and gas-fired CHP plant. No electrical connection
40	Huhneberg House	Huhneberg, Switzerland	1991	Highly insulated masonry	Ground-coupled mechanical ventilation system and central CHP plant. Similarities to Wadenswill
41	Autonomous Solar House	Coppenbrugge Dorpe, Lower Saxony, Germany	1989	Timber frame structure with 400-600 mm cellulose fibre. Active solar system with small seasonal store, within the house.	Privately funded. Initial technical problems. Backup fuel for space and water heating now about 4kWh/m²yr
42	Ecological Exhibition House	Sindelfingen, Baden-Wurttemberg, Germany	1990	In-situ concrete load-bearing internal walls. External walls a non-load-bearing timber structure, filled with cellulose fibre.	Demonstration of environmentally-sound building techniques, funded by state and municipal government. Open to the public for a year
43	Ecolonia	Alphen a/d Rijn, Netherlands	1991-92	Mostly masonry	Nine areas, all on a different theme related to reduced environmental impact
44	Brug House	Brug, Switzerland	1991	Highly insulated house with advanced mechanical systems, including earth tube ventilation system	Using 10 kWh/m²yr, performance now matched by other schemes of its kind
45	The Zurich Advanced House	Zurich	1992	Masonry	Another Swiss 'zero-energy' house

additional projects 46-52

VARIOUS CONSTRUCTION METHODS

Elsewhere in Europe

	PROJECT	LOCATION	DATE	CONSTRUCTION METHOD	COMMENTS
46	The Grunningen Advanced House	Grunningen, Zurich, Switzerland	1992	Masonry	Another Swiss 'zero-energy' house
47	The Magic Floor	Sweden	1993	Mixture of timber frame and hollow-core precast concrete ground floor	IEA Task 13. 70% of gross heat demand met by passive solar and internal gains
48	Advanced Houses	Lillehammer, Norway	1993	Timber frame	IEA Task 13. Advanced window design
49	Ultra-low-energy home	Haringkavel, Boskoop, Netherlands	1993	Masonry	Sponsored by NOVEM
50	The Ultra House	Rottweil, Germany	1993-94	Masonry	Two-storey 130 m^2 detached house with cellar. German contribution to IEA Task 13. Predicted energy use, excl. solar, about 35 kWh/m^2yr. Novel window design
51	The Energy Autonomous House	Woubrugge, Netherlands	1993	Masonry	5.4 kW roof-integrated-PV system and solar thermal collectors supply all the house's thermal and electrical needs.
52	The Ultra House	Berlin, Germany	1993-94	Masonry	Active solar with seasonal storage. Resembles Wadenswil and Rottweil Ultra House. However, despite a poorer solar climate, the predicted non-renewable energy use is lower, 15 kWh/m^2yr.